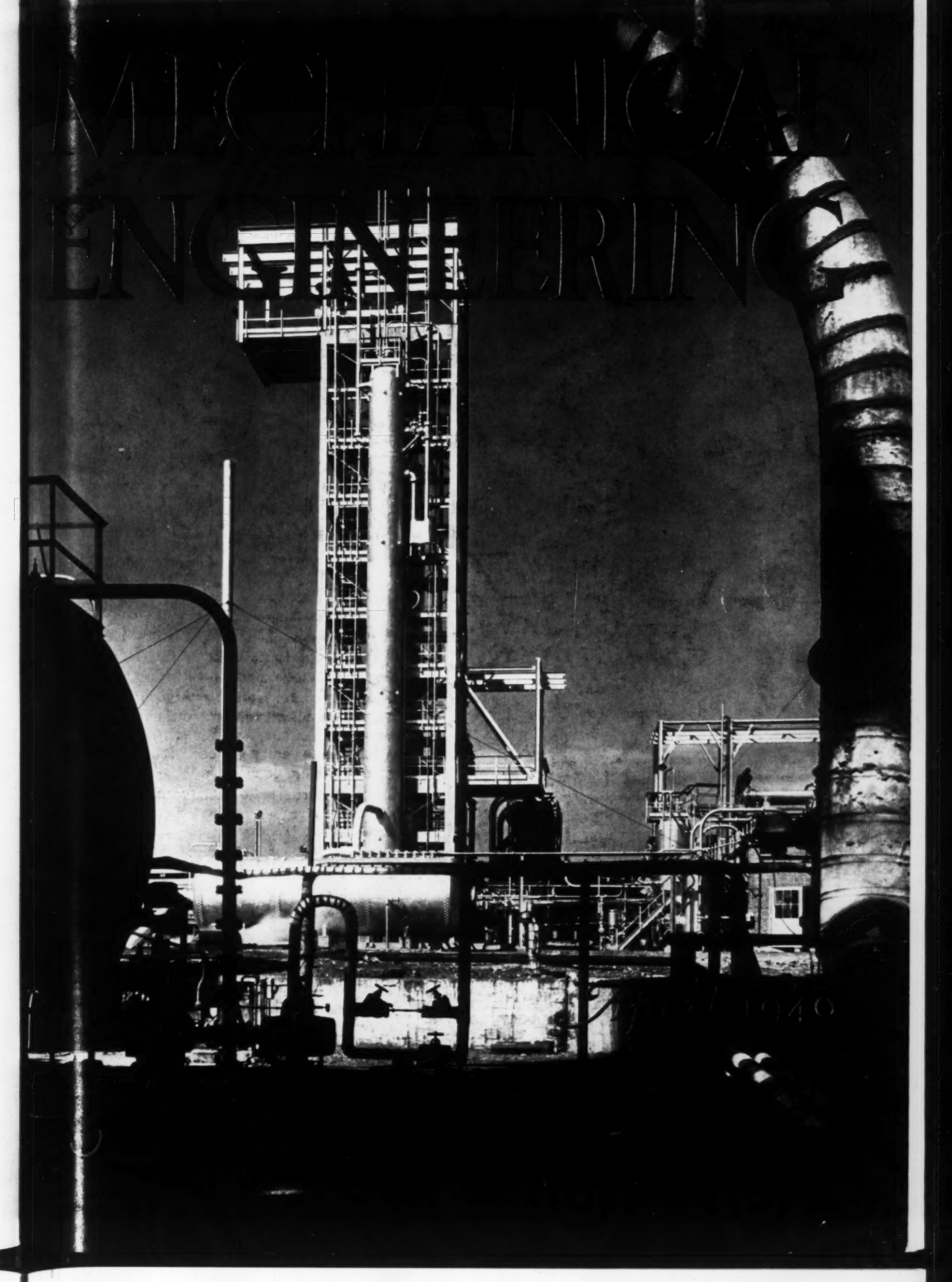
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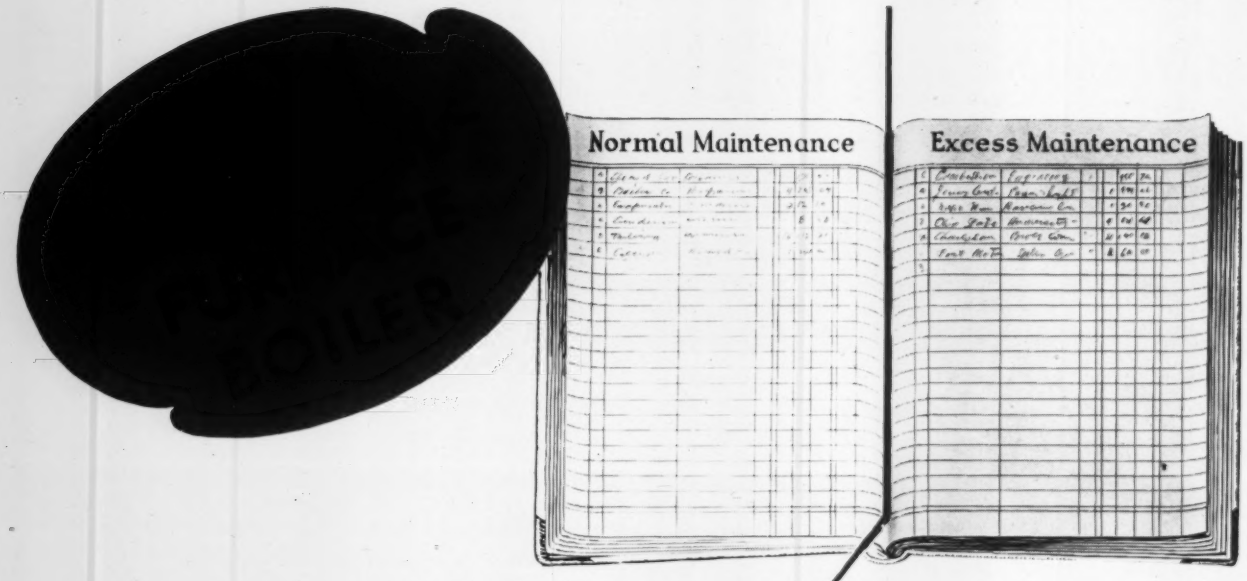

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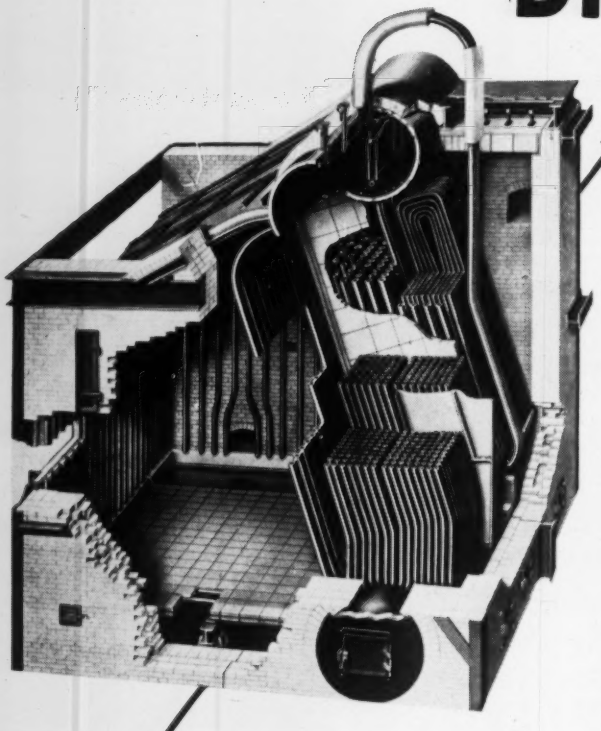

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MECHANICAL ENGINEERING

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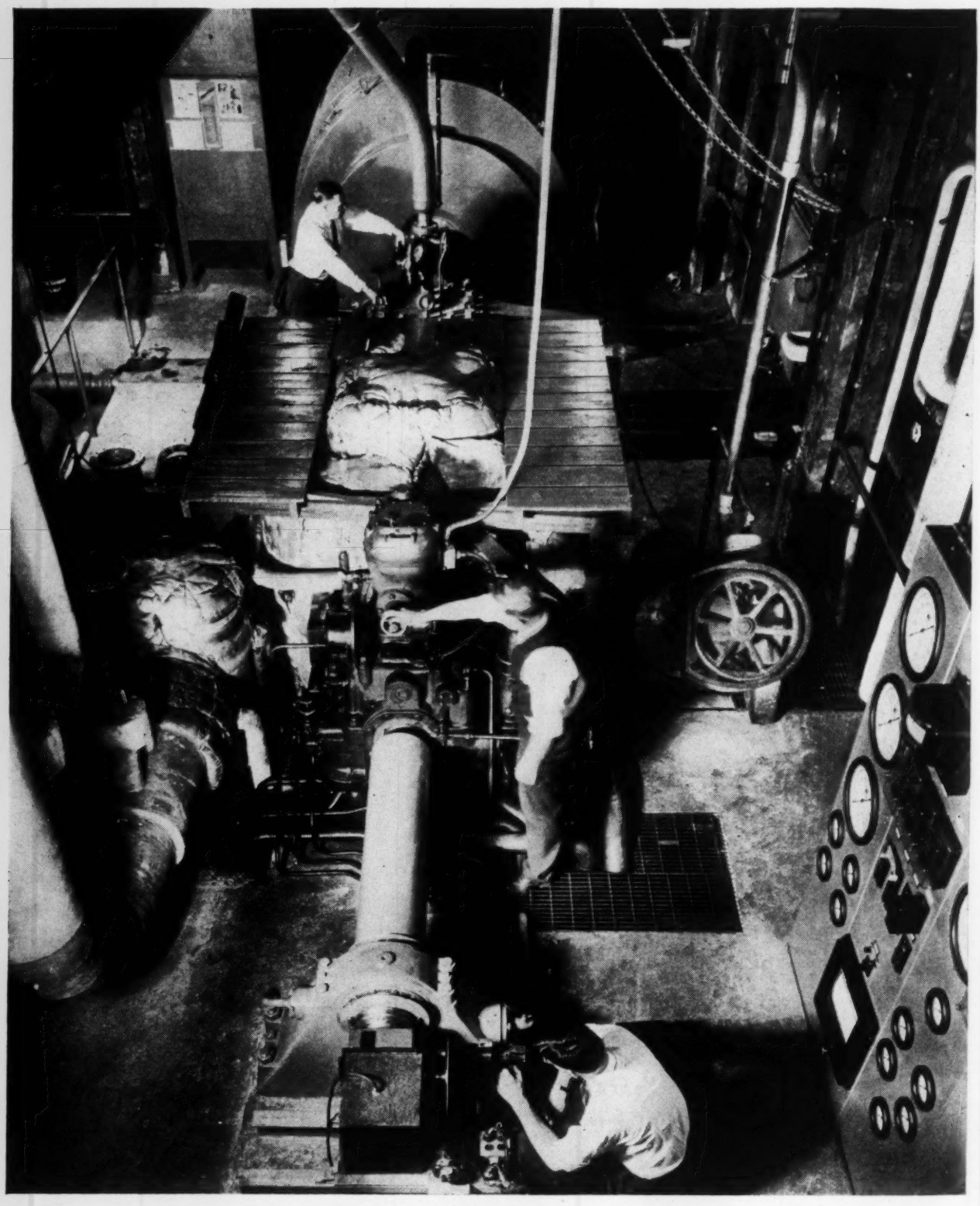

Turbine-Blade Research at the Philadelphia Electric Company

(*See article on page 275. In the foreground an operator is adjusting an arc lamp from which a light beam enters the hollow extension of the turbine shaft and through it to the turbine rotor and to a mirror set in the tip of a turbine blade, whence it returns to the camera to be seen at the bottom of the picture. Here vibration records, like those in Fig. 3, page 276, are made by the light beam.*)

MECHANICAL ENGINEERING

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GEORGE A. STETSON, *Editor*

A.S.M.E. Sixtieth Anniversary

EVERY member of The American Society of Mechanical Engineers knows—or he should know—that April 7, 1880, marked the birth of the Society.

Eleven years ago, at the peak of the wave of the prosperity of the twenties, elaborate plans were laid for a Fiftieth Anniversary, celebrated in April, 1930, at New York and Washington, with delegates and medalists from the entire world in attendance and a commemorative issue of this journal which reviewed the Society's history, did honor to its distinguished members, living and dead, and presented reviews of technical developments in the field of mechanical engineering of that fifty-year period. Although this celebration took place in the dark days that followed the debacle of November, 1929, a spirit of optimism still prevailed, and relatively few persons foresaw the long period of distress and economic depression that was commencing. The unbounded opportunities of the recent past, ephemeral though they proved to be, were too vividly before men's eyes to permit them to see in the gathering twilight of blighted hopes and unemployment. The slogan of the occasion was, "What is not yet may be," brave, hopeful words that have not lost their meaning for the world at large, in spite of the greater darkness that is now engulfing the entire "civilized" world.

The history of the sixty years of the Society's life is available in many forms and places. A brief survey of it, the most recent to appear, formed the opening article of a series entitled "The A.S.M.E. Today," and will be found in the October, 1939, issue of MECHANICAL ENGINEERING, page 745. But the publications of the Society, the technical papers, and routine records that have filled the Transactions and this magazine under its several titles, provide the most abundant proof of the service rendered. Truly these demonstrate in many conspicuous cases that what was not then has come to be. Why should we despair of the future?

Our concern today is not with the past but with the present and the future, not with records but with trends, not with what has been done but with what lies at hand to do. Broad objectives change but little, but the ways in which they may be approached vary with the temper of the times. What are the present trends?

It is a common practice to remind ourselves that sixty years ago we knew nothing of such present-day achievements as the electrical industry, the automobile, the radio, aeronautics, a host of common and important materials, everyday comforts without which we would, for a while at least, find our lives difficult, and modern techniques of production and the administration of industrial enterprises. We recall the statement that there was nothing left to discover, invent, or develop, just as today we listen to laments about vanished frontiers, technological unemployment, and lack of living space and access to raw materials. But we hear less often about the rebirth of physics and chemistry, the industrialization of research, the growth of educational opportunities at all levels, the greater army of educated men, particularly in scientific and engineering fields, the increase in the number of persons engaged in the service fields of economic life, and the improvement in the national health and standards of living. Collectively we have gained and not lost ground, even though the times are out of joint. We have deployed into wider fields, and this fact gives direction to the trends discernible today.

Without making a complete survey of these trends as they apply to the A.S.M.E. or to assess their relative values, let us look at some of them. We are learning to engage more effectively and wholeheartedly in joint activities. Numerous cases spring to mind, starting with those early efforts of the Engineering Societies Library and the Engineering Societies Building that initiated this movement shortly after the turn of the century. Cooperative undertakings are growing and are extending beyond the narrow limits of the Founder Societies where they began. Hundreds of organizations are now involved and more will be brought into future efforts.

Concern for the social and economic consequences of his work is engaging the attention of the engineer. Pressure is no less from without than from within. The Juggernaut of so-called liberalism is careening toward distant Utopias with a speed that exceeds the velocity of the sound of its own fury, and carries with it the more realistically minded engineer. But as a trend, this economic and social onrush must be noted.

Questions of economic status and professional adolescence confuse the engineer. The entire world, including the engineer, is rapidly discovering that its way of life is conditioned by rapidly advancing science and technology. In the maladjustments that became acute in one phase during the depression and are acute in another as a result of war, the imagined security of the past has been swept away or is tottering. Everywhere men are struggling to maintain their economic status and to improve it. Engineers are caught up in the universal conflict. They are, and they will continue to be, concerned with it, whose problems range from fair wages to "professional recognition," economic, social, and legal.

Nor has education escaped. Few enter engineering

today except by way of the college or engineering school where every factor is in a condition of readjustment, from financial support to quality and extent of curricula. The sharp differentiation between "arts" and "engineering" is at once disappearing, as the colleges pay more attention to science and the engineering schools more to the "humanities," and widening, as graduate study becomes more general in both. The influences of this trend toward a greater number of college-bred engineers and education on a broader base constitute a very hopeful trend in engineering.

As a direct consequence of economic conditions and educational background, the problems of youth are becoming more acute and give rise to another trend in the direction the A.S.M.E. is heading. Remarkable progress in student-branch and junior-group activities have set the pace for this trend. The increasing tempo of progress and competition accelerate it and emphasize its importance. In the problems of young engineers appear, in concentrated form, practically all of those of engineers of all ages—technical and economic problems that cry for solution.

Another trend is research, a word associated a generation ago with those "ivory towers" of college laboratories. Today, research is to be found everywhere, but nowhere is it so lavishly supported as in industry where it is the insurance against obsolescence and bankruptcy. The A.S.M.E. cannot afford to neglect this trend but should actively direct as much of it as opportunities permit. Without attention to it, the Society will meet the fate of the industries that neglect it and will fail in its obligation to the art of engineering the Society was organized to foster.

Last of this crudely outlined and woefully incomplete list of trends is one that is ever-present in the world in one sense but one that is, in a special sense, just visibly taking shape—reconstruction. Among the causes of the depression and the war some will place man's failure to make best use of his scientific and engineering knowledge. Men have yielded to their predatory rather than their creative instincts. Reconstruction must follow both the depression and the war. To a large extent reconstruction must depend upon engineers, alike for the rebuilding of shattered homes and cities, for the reassertion of the creative spirit of production as opposed to destruction, and for the removal of those handicaps of insufficient resources which exist in one form or another everywhere. Reconstruction will be the task of youth as it is the challenge. The youth of today may well look upon the present world with more than the usual amount of dissatisfaction, but the youth of tomorrow are treading close on their heels to call them to account. Here again, in the reconstruction that inevitably must come, the A.S.M.E. must, if it does not miss its greatest opportunity, direct a gradually growing trend.

In the realization of these and other trends, can any one doubt that there is work to do or that the A.S.M.E. has before it greater opportunities than it developed in the last sixty years? Let our sixtieth-anniversary celebration take the form of a dedication of the A.S.M.E. to the accomplishment of the tasks that lie ahead.

Jobs for Others

IT IS easy to dogmatize about the other fellow. Passing through some of the economic backwaters of the American scene one finds himself wondering why the benighted inhabitants don't ever clean up their dooryards or tack a flattened tin can on a leaky roof, forgetting that one's own dooryard or roof, figuratively if not literally speaking, would be the better for a rake or a hammer, intelligently applied.

Why don't educational institutions teach youth to be self-reliant and train them in initiative? The pert answer is that they do, but what can you expect of young people these days? But do they; and don't most of us take the traditional, the obvious, the "secure" way? Isn't a large part of our educational effort directed toward training young people for specific jobs—to be a clerk, stenographer, or bookkeeper, to teach school, to work in the local shoe factory, or for the city, or some large institution where the pay envelope is as certain as death and taxes? To be sure. Most of us followed this pattern, and it looks ridiculous for us, lying in our soft beds, to ask the other fellow, why don't you make yourself a nice bed and lie in it? We may say, I wish I had tried the hard way, I'd have been a better man for it; but we say it softly and hope no one will hear us.

Nevertheless, it is a practical question, and the world would be better off if a practical answer were to be found for it. Certain it is that the world would be much worse off than it is if a few persons had never found answers to it or were not, through courage or necessity, or both, finding such answers today.

The primary school prepares for the secondary school, the secondary school for the engineering college, and the engineering college for the large employers of engineers, quite naturally—for the steel mill, the railroad, the public utility, the national manufacturer, and the like—established going concerns that have jobs to offer. The boy slips easily into a vast and complicated machine, confident that if he does his own bit well there are hundreds of others to worry about the details. Someone will devise new products, someone will keep production going, someone will find markets and manage sales, someone will attend to financing, balance sheets, and pay rolls. A cog in a wheel but such a well-greased cog in such a smoothly turning wheel. And if it stops—

Many wheels have stopped turning. All we want, cries youth, is a job—a chance to work. But is that all the country wants? Suppose youth were to say, I want a chance to give someone else a job? Suppose the colleges added to their talks, on how to find and hold a job, one on how to make a job and employ labor. What then? Practical difficulties arise, to be sure, difficulties not every man can overcome. But the change of emphasis is what the country needs. We all think of society's obligation to hire us—too few of us think of our obligation to find a job for ourselves that will lead to giving employment to someone else as well. It is the hard way, the way too few of us have taken since the rise of big corporations, but it is the way all big corporations started. Perhaps the schools can do something about it.

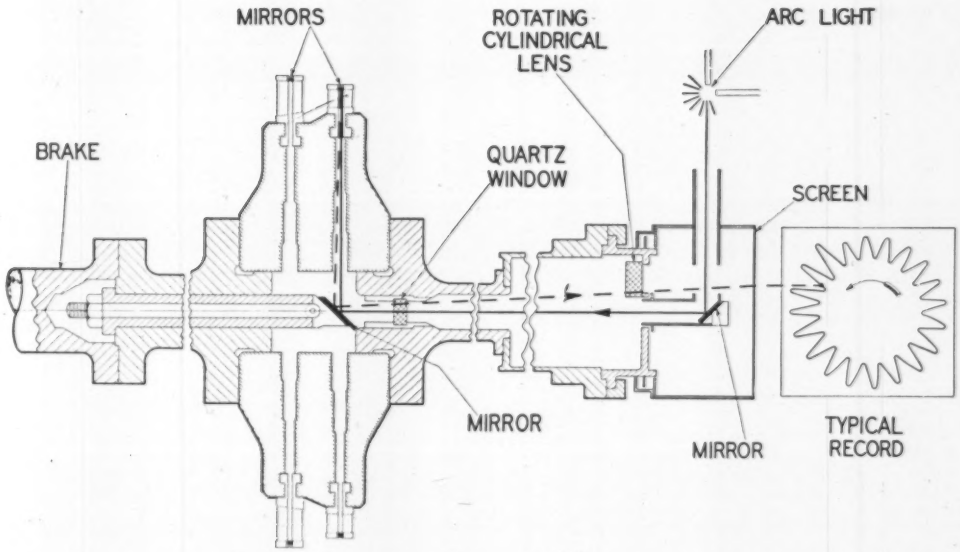

FIG. 1 OPTICAL SYSTEM, IMPULSE-BLADE RESEARCH

SUPERPOSED TURBINE BLADE RESEARCH

By F. T. HAGUE

MANAGER, ENGINEERING-STEAM DIVISION, WESTINGHOUSE ELECTRIC & MANUFACTURING CO., SOUTH PHILADELPHIA, PA.

SUPERPOSED turbines pass from 1 to 1½ million pounds of steam per hour at a density five times as great as that in the low-pressure turbines with which they are in series, and the steam temperature is 900 F. The passage of a large volume of dense high-temperature steam through the first wheel creates conditions unlike those with which there has been much previous experience. For each 20 F increase in temperature in this region, the plastic flow or creep rate of steel is doubled and other physical characteristics are adversely affected.

To obtain good economy at partial loads the incoming steam is fed to this first wheel at only a portion of its periphery, and the blades passing into and out of this steam jet receive a most violent shock each revolution of the turbine. To form a mental picture of this shock imagine an impulse blade moving 350 mph abruptly entering a dense steam jet moving 1200 mph. Shock and vibration of these first-row blades are aggravated by this intermittent steam loading. This intermittent steam loading has been conventional for many years on all sizes of condensing turbines. It has been only on those few machines of the large superposed class that its use, in an endeavor to develop the ultimate in partial load efficiency, has caused some blades to break at their root where they are fastened to the spindle. The prompt failure of three successive sets of physically larger blades on a large superposed turbine indicated that something more than brute strength is required of impulse blades in this application when intermittent steam loading is involved.

A research was initiated to develop a better understanding of the conditions affecting the operation of impulse blades in superposed turbines. Nothing short of actually photographing the blades' movements under actual operating conditions promised to give adequate and accurate records of the stresses imposed on these blades. An ingenious optical method, Fig. 1, of accomplishing this has been devised and the turbine blades are made to write their own story in a camera adjacent to the turbine. Tiny mirrors are mounted inside eight different blades in the first and second blade rows. A light beam projected through a hole in the turbine shaft is reflected by an inclined mirror to the mirror in the whirling blade being photographed and then back out through the shaft to the stationary camera or viewing screen. By taking pictures every one-half second on moving film, an exact record of blade performance is obtained for any desired set of operating conditions. The turbine optical system is so proportioned that the movement of the impulse blade is magnified 250 times by the movement of the light spot.

The first development turbine with this built-in optical system has been in operation in our plant since September, 1939. More than 20,000 photographic records have been obtained showing the performance of impulse blades in a wide range of operating conditions. Single blades and shrouded blade groups have been tested in the first and second rows of a Curtis stage under available plant steam conditions of 400 psi and 600 F. Although the pressure and temperature of our plant are not those met in commercial service, nevertheless the photographic

Presented at a meeting of the Philadelphia Section, Philadelphia, Pa., Feb. 27, 1940, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. Portions of the paper relating to demonstrations conducted by R. P. Kroon have been omitted.

method developed will apply with equal success to any commercial steam conditions.

THE EVIDENCE OBTAINED

Examination of a typical photographic record of a blade's movements during one complete revolution of spindle shows that the blades vibrate like a tuning fork, Fig. 2. The vibration is increased as a blade enters the steam jet. The blade vibrates while in the jet and continues to vibrate with slowly decreasing amplitude after it leaves the steam jet. This slowly decreasing amplitude of vibration is significant because it is caused by the internal molecular friction of the blade material, i.e., the damping characteristic of the blade steel. The blades vibrate at their natural frequency. This is true whether the steam shock is light or strong and is independent of turbine speed. The natural frequency of vibration is fixed by the blade design and material.

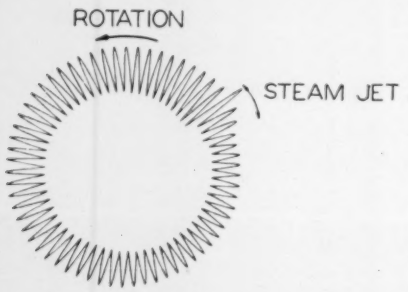

FIG. 2 TYPICAL BLADE VIBRATION IN RESONANCE

In superposed turbines the frequency of vibration of first-row blades is about 2500 cycles per sec, one of the highest notes on a piano, or 200,000,000 cycles per 24-hr day. Blades stressed at their fatigue limit usually break within 10,000,000 cycles. This explains why failures of blades in the first row of superposed turbines usually develop quite promptly, if they fail at all, particularly if the turbine is loaded at half load or below where intermittent steam loading is involved. As the turbine load is increased the steam jet covers more and more of the periphery of the first wheel until, above three-quarters load, steam is applied throughout the entire periphery of the first wheel. When the full-admission condition is established, this vibratory stress condition is eliminated.

WHAT THE STUDIES SHOW

As in diagnosing a new ailment, it is important to know which factors affect the condition and which do not. The optical test studies and practical experience have shown both.

Strange though it may seem, the amount of load on the turbine has relatively little to do with the maximum blade stress. The factors which influence this condition are mechanical resonance and the damping characteristic of the blade steel.

Mechanical resonance involves a relationship of two frequencies, and in turbines one of these is the frequency of the shock from the steam jet. The other is the natural vibrating period of the blade. When these two frequencies are in such a relation that one is an exact integral multiple of the other, resonance results. When resonance is produced in any mechanical system, the magnification of stress is limited solely by the damping of the material used. The ability of a turbine blade to operate without breakage depends largely on whether the damping within the blade is sufficient to choke the vibration established during resonant conditions.

RESONANCE

With any constant turbine load, the magnitude of blade stress has been found to vary over a four-to-one range as the turbine speed is changed as little as 2 per cent. It is this four-to-one range or build-up of blade stress at constant turbine load which is the cause of the breakage of blades in superposed turbines. In Fig. 3, taken from an actual turbine in constant-load operation, the only variable is a slight change in turbine speed; in this particular test turbine it took a change in speed of $1^1/_3$ per cent to pass from the resonant condition to the nonresonant condition.

"Out of resonance" is illustrated on the left of Fig. 3 and "in resonance" on the right. Fig. 3 consists of seven or eight photographic records of blade performance taken one-half second apart as the turbine speed is slowly changed from 3090 to 3130 rpm. In order to get all of these records on one chart to show them in sufficient scale they are overlapped and for sake of clarity all of the overlapping records on the first and last have been eliminated. The first and last records represent "out of resonance" and "in resonance" blade performance.

In the "out of resonance" record, Fig. 3, when the blade passes the steam jet, the steam jet hits the blade out of phase with its existing motion and a new order of frequency is established. It is that continual hitting of the blade out of phase with its existing motion as it passes through the steam jet that prevents the blade from building up its vibration to a large amplitude and its stress to a large value.

In contrast to this, the record on the extreme right of Fig. 3 indicates that as the blade passes through the steam jet there is no variation whatsoever in the frequency. In that case conditions required for resonance have been established. The steam jet is hitting the blade in phase with its existing vibration and, as a result, vibration amplitude is built up to a large value, controlled and limited by the damping capacity of the blade steel. It is that condition which increases the blade stress by a factor of four to one, even though the turbine load is constant, and it is that amplification of blade stress which breaks the blades in superposed turbines.

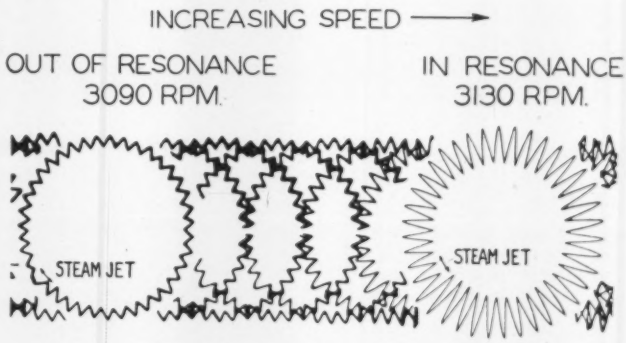

FIG. 3 TYPICAL RECORDS OF BLADE MOTION AT CONSTANT LOAD

It is obvious, therefore, that the impulse blading of large superposed turbines must be designed to operate at safe stresses under resonant conditions. Although actual turbines run at constant speed, the natural period of blades will vary more than 10 per cent by virtue of manufacturing variations, changes in operating temperatures, and the like, so that some blades will be in resonance under all operating conditions.

DAMPING

One phase of the investigation has been to explore the factors affecting damping. Several important damping relationships have been discovered.

1 Damping is not constant but increases with blade stress and is extremely low at low stress, Fig. 4. It is as important to know this relationship as to know the strength of steel.

2 The damping characteristics of different steels vary

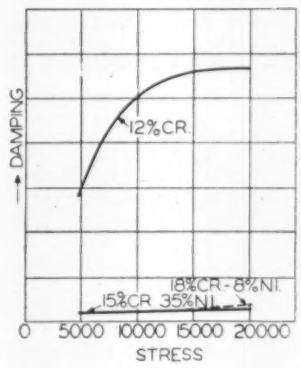

FIG. 4 DAMPING OF BLADE STEELS, 700 F, 750 CYCLES PER SECOND

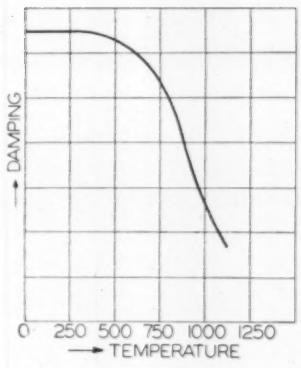

FIG. 6 DAMPING OF 12 PER CENT CHROMIUM STEEL, 750 CYCLES PER SECOND, 20,000 PSI

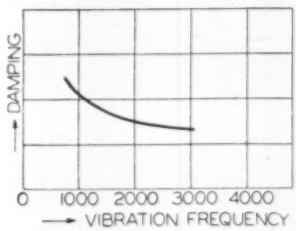

FIG. 5 DAMPING OF 12 PER CENT CHROMIUM STEEL AT 1000 F

widely. The widely used 12 per cent chrome steel has more damping in its usable application range than any other material yet investigated. The materials of the chrome-nickel class that excel in high strength at high temperatures have about one tenth as much damping as 12 per cent chrome steel.

3 Damping becomes less as the frequency of vibration increases, Fig. 5. This means that the increased stiffness of heavier blades does not result in much lower blade stresses.

4 Damping decreases rapidly at higher operating temperatures, particularly beyond 750 F. At 100 F the damping is only one third as much as at room temperature, and is decreasing precipitously, Fig. 6.

SEPARATE DAMPERS

These findings suggest the possibilities of applying some sort of separate dampers to the blades. We are investigating separate damping means that increase the damping of blades by five to ten times. A steel capsule, partly filled with material that is fluid at operating temperatures, can be inserted inside a blade and maintain its full damping capacity up to 1500 F.

We do not mean to infer that superposed turbines for present-day standards of temperature and pressure must have separate blade dampers to operate safely. This research merely points out that such means would greatly increase the factor of safety of impulse blades and such means may be required to meet future operating conditions.

Our research shows that impulse-blade stresses can be calculated. The calculation system developed by R. P. Kroon based on this resonant method of analysis permits a rational evaluation of controllable design features and makes it possible to predict whether a certain design is safe.

EXPERIMENTAL TURBINE AT SCHUYLKILL

Building on the experience with this experimental turbine at South Philadelphia, a second one with full-size impulse wheel, duplicate of the impulse stage of the 50,000-kw West Penn unit, was built for research study of blade performance under 1250 psi, 900 F steam operating conditions. This turbine with its 10,000-kw generator and 15,000-hp water brake began testing operation in February, 1940, in the Schuylkill plant of the Philadelphia Electric Company. This turbine takes steam from the station 1250-lb steam lines and exhausts into the low-pressure 240-lb lines, permitting its operation as a superposed unit without interference with the station's regular operation. This turbine is built solely for research purposes and has many special constructional features, including single and double blades, separate blade dampers, different shroud attachments, and various blade groupings. The optical system will record the performance of sixteen different blade combinations. Two rotors are being built with different blade designs and the presence of the 10,000-kw generator will permit life tests by loading into the Philadelphia Electric system.

Reference to this unit must acknowledge the joint research relationship with the Philadelphia Electric Company, who are making available the use of the station, operators, and steam supply. This contribution to research on a central-station industry problem is a tribute to the broad viewpoint of the management.

Today we are making a progress report on our research studies. To maintain proper perspective it should be remembered that the impulse-blade problem has been critical on only a few large superposed turbines, which, although an important factor in the industry, are nevertheless a small portion of the turbine business. We have an excellent tool for diagnosing the duty and stress of impulse blades. From the research studies of this installation will come a visual record of impulse-blade operation which will expedite the engineering solution of the impulse-blade problem. It has been our experience that research problems are more readily solved when measuring instruments are evolved which make possible quantitative measurements of occurring phenomena. We have that instrument in this photographic method.

TURBINE IN PROCESS OF ERECTION

(The experimental 1250 psi, 900 F steam turbine at Schuylkill Plant of Philadelphia Electric Co., in process of erection. To flange at left a 15,000-hp water brake will be attached, and beyond that a 10,000-kw generator. To flange at lower right will be attached extended hollow shaft through which light beam passes. See also frontispiece of this issue.)

ADMINISTRATIVE ORGANIZATION *in* BUSINESS *and* INDUSTRY

By L. A. APPLEY

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THE fact that a session of the Annual Meeting of The American Society of Mechanical Engineers is given over to a discussion of administrative organization is of deep significance in itself. It is further evidence of a rapidly growing appreciation of the importance of this activity. In all types of organizations an increasing realization is being evidenced that sound administrative procedures and practices are not just inhaled out of the air by those who are placed in positions requiring their use. Government, industry, business, and other organized groups have suffered to some extent because of the belief on the part of many people that when a man is placed in a managerial position, he immediately becomes endowed with certain knowledge and capacities required for successful administration.

Technical knowledge of operations and past performance have been overemphasized in the selection of individuals for supervisory and executive positions. These two factors in themselves are of little use without a knowledge of and a capacity for sound administration. Speaking at the Seventh International Management Congress in Washington in 1938, Dr. Elton Mayo made this observation: "Empirically—fortuitously—we still happen to light upon men to lead us, men who have the knowledge, the keen insight, and the balanced judgment an administrator must possess. In a difficult world how long can we expect happy accident to supply our most urgent need?"[1]

A common statement is that there are not enough individuals naturally endowed with administrative ability to fill the supervisory and executive jobs that exist. If this is true, then there are two alternatives: One is to allow those not so endowed, and yet in supervisory jobs, to continue to perform unsatisfactorily; the other is to improve the supervisory performance of such individuals by giving them the benefit of the experience of those who have been successful in similar positions. The second alternative seems to be the one that is being increasingly accepted by modern managements. An organized attempt is being made to increase the knowledge and the abilities of those who are in positions of administrative responsibility.

The A.S.M.E. has provided this session toward that end. It is our sincere hope that the papers, of which this is one, and the discussions that are to follow will contribute constructively to our thinking on this subject.

ADMINISTRATION—MANAGEMENT

There seems at times to be much confusion in the use of the terms "administration" and "management." There are those who speak of staff activities as being administrative, and those who speak of line activities as being managerial in nature. Still others reverse that application. It would seem essential that we clarify our thinking as to these particular terms.

A study of Webster's dictionary discloses that the two terms —administration and management—are synonyms. Therefore, in using them, we should consider that we are talking about one and the same type of activity. Administration is management, and management is administration. They mean complete responsibility for and control of the activities involved. This interpretation may be incorrect, but, armed with the best sources at our command, we feel we are justified in accepting this viewpoint in order to clarify any discussions involved on the subject. Therefore, in using either of these terms in this discussion, we are referring to both.

Administration involves two basic factors, planning and control. All of the functions of an executive might be reduced to one over-all statement by saying that he is expected to develop definite objectives; to plan procedures which, if followed, will accomplish those objectives; to establish controls to see that the action of his personnel follows the plan. In other words, he continually compares present accomplishments with objectives and determines ways and means by which the gap may be closed between actual accomplishment and objective.

The challenge to any management is the difference between practice and approved policy. A successful administrator has his plans definitely and completely established, and he is accurately advised as to current practices as compared with the plan. Unless so fortified, his decisions cannot be sound, except by pure chance.

POLICY FORMATION—PLANNING

It has been stated that there are two major elements in sound administration: One is planning and the other is control. Let us consider at this point the first of these two—planning.

Policy is one of the most misused terms in organization circles today. It is often used as expediency rather than as fact. There are constant arguments as to how definite the policies should be; as to whether or not they should be in writing; and as to how widespread knowledge of them should be. Words sometimes change their meaning with use and therefore become confusing. It would seem advisable from time to time to check back with the source of proper interpretation in order to keep words and terms from straying too far from their original intent.

In consulting the dictionary we discover that policy is a plan of action. If properly developed, a policy will tell us what to do in a given situation in order to secure the desired result. It would seem reasonable to assume that if a policy is a plan, then, to be of any value, it should be in writing. A person might have in his mind an idea as to how he wishes to build his new house, but he will never get that house built the way he wants it until he has reduced to blueprint form that which is in his mind. The administrator will never accomplish with his organization what he wishes to accomplish until he puts on paper the plan to be followed.

If it is agreed that a policy should be in writing in order to be of any practical value from an administrative angle, then it is important to consider what it should include. So far no

[1] Proceedings of the Seventh International Management Congress, p. 199.

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disagreement has been expressed with the thought that a written policy should include these three basic facts: objectives, procedures required to reach the objectives, and assignment of the steps of the procedures to individuals as functions.

Any plan should include a picture of what you will have when you are done. A policy should include objectives which state the conditions that will exist if the policy is properly applied. A marketing policy should disclose the amount and the distribution of desired business, the expense for doing that business, a just realization on that business, and any other conditions that need consideration. An operating policy should disclose the type of service to be rendered to the marketing department and the consumer, a just cost at which such services should be rendered. A labor policy should disclose the mental attitudes, the type and amount of skill, the exact working conditions and relationships, and the particular benefits that should exist in respect to the personnel. Such objectives constitute goals toward which the organization and each individual in it can direct effort.

Having established objectives or, in other words, made a drawing of what the completed job should look like, it is then necessary to put the best possible thought into the development of a procedure required to accomplish the objectives. The mistake made by many administrators has been to outline to their organization what they expect to have accomplished and then to leave it to the individuals concerned to accomplish it as best they can. This, of course, is a broad-minded and fair attitude, but it does not provide those concerned with all of the knowledge and experience available which would be of assistance to them in determining how they should go about their tasks. Therefore, the administrator should exhaust every source until he has finally set up a definite procedure representing the best thinking in the organization as to what has to be done to bring about the desired results.

Having determined what steps should be followed in order to accomplish the objectives of the policy, it is then essential to assign these steps to individuals as responsibilities. If this is not done, individuals, departments, or various units of the organization will be trying to do the complete job, rather than a certain important part of it. The situation would be similar to the automobile plant, with every group of workers trying to make a complete automobile instead of each group working at an assembly line with a particular part of the automobile to make or assemble. In the first case, the finished product would be a matter of chance and there would be no uniformity as to style or quality of the products released by different groups; in the second case, all groups would be contributing to a finished product which meets desired specifications.

Representative Wadsworth of the New York State Legislature has been in charge of a study of "The problem of a man over 40." In connection with his study he has talked with many industrial executives and workers. He has stated that in many instances top management has said to him, sincerely and honestly, that they had no policy with regard to the man over 40. In talking with subordinates in the organization, he found that there were policies, resulting from practices, that either favored or put the man over 40 at a disadvantage. If in such cases companies concerned had had policies developed according to the principles just outlined, such a condition could not prevail except in cases of deliberate insubordination.

PLANNING VS. APPROVAL

A question just as old as "Which came first, the hen or the egg?" is the one, "How busy should an executive be?" There are those who believe that the proper executive atmosphere is that of long hours, missed lunches, batteries of telephones, last-minute traveling reservations, dictaphones by the bedside, and the like. There are others who say that the best executive is the one who never gives the appearance of being rushed or busy; who can do his work within the limits of office hours; who always has the time to discuss anything with anybody; who delegates all responsibility; and can occasionally play golf without fear of the business falling apart in his absence. Agreement on the answer to that question will probably never be reached because management is largely a matter of personalities and not systems. There probably is a medium ground between the two viewpoints that comes more nearly to being correct than either of the extremes just presented.

However, there are some features of executive practice which seem to meet general approval. One is that the number of items or activities that a manager has to sign or approve can be greatly overdone. There are men who believe that a real executive job is sitting at a desk signing and approving piles of forms and papers and proposals. The number of times a man has to sign his name does not indicate the extent of his authority.

Another principle which is fairly well accepted is that authority should be delegated within definitely defined limits. Some people do not delegate authority because they have not established limits to control the use of authority and each individual case has to be considered on its own merits. There are some, for example, who maintain that authority for salary changes cannot be delegated. Their feeling is that all salary changes should be approved by a salary committee or some particular executive of high standing. Such persons usually do not have any established salary group limits within which changes are made. If time is taken to establish income limits for each job—maximums and minimums—then it is a simple matter to delegate authority to any executive or to any supervisor to administer salary changes within those established limits.

These limits, within which authority can be granted, should be included in policy. The development of a policy on a sound basis would establish the roads upon which we are to travel and we would have the privilege of traveling on that road in any kind of a vehicle and with any degree of speed we care to, just so long as we stay on the road and reach our destination at the established time.

In other words, the more administrative planning there is, the better policies are constructed and the less executive approval required. If administration properly establishes objectives, procedures, and responsibilities in connection with the major activities of the operation concerned, more time is available for further planning and greater perfection in present planning.

The complaint continues to arise from many sources that executives and supervisors haven't time to do long-range planning because each day brings sufficient duties to fill the day. Somehow, sometime, we must neglect a day's duties, or get somebody else to do them, so as to establish the course for tomorrow before the ship strikes a shoal, sinks, and tomorrow has no duties.

ADMINISTRATIVE CONTROL

Keeping in mind the two basic factors of administration, planning and control, let us assume that the element of planning has been well performed through the establishment of written policies which outline objectives required, procedures for reaching those objectives, and the assignment of steps of the procedures to individuals as functions. We then turn our attention to the element of control.

A study of many organizations of varied types discloses an unfavorable balance between planning and control. In some instances there is a predominance of planning without sufficient

control to see that the plans are carried out, and in other instances there is an excess of control needed because of the absence of planning.

It is most important in considering this topic to define what is meant by control. Sound administrative practice sets up in an organization required media to insure understanding by all concerned of what is expected of them and sufficient help and information so that those individuals are able to do what is expected of them. Such media must also provide for the development of an attitude of desire to do what is supposed to be done. Control rightly implies proper supervision which necessitates the elimination of many of the routine details which executives and supervisors find themselves required to do and which take valuable time away from supervisory activities.

Control does not imply centralization of authority. It does not mean policing or inspection. On the contrary, the best type of control is through decentralized authority. It requires the delegation of responsibility and authority and the development of people who are able to accept both.

Through a misconception of what constitutes administrative control, there will be found in some organizations tremendous duplication of effort and an abnormal amount of checking of what others do. Each stratum of the organization should carry its own load and only a small part of its activities should require higher executive approval. For illustration, it should not be necessary for five or six different executive groups or persons in an organization to approve the expenditure of $50,000. One group should have the approval up to $10,000; a higher group everything from $10,000 to $20,000; another group from $20,000 to $30,000; and the final group anything above that. All activities of the organization should be analyzed to discover how much authority and responsibility different executive levels have.

A successful method of insuring proper administrative control is through what is known as an activity analysis. In group discussions, the basic activities of the group concerned should be carefully studied. Break the activity down into its various subdivisions. List the individuals who have something to do with each of these subdivisions and clearly define the nature of the relationship of each individual.

Ten different people might have some relationship with one activity. Unless they are in identical positions, each of these persons has a different type of relationship with that activity. One person might initiate it; another review it; another endorse it; another render advice in connection with it from some particular angle; still another might check it against something else; and finally somebody has to approve it. Such clarification fulfills the manager's responsibility toward administrative control. It is then up to his staff to supervise people concerned in such a way that the activity is carried on as approved.

There are those who plead the cause of individualism and personal initiative. They sometimes feel that such clarification restricts the activities of people in the organization. However, lack of clarification brings about greater restrictions if we only knew it. We might as well be honest and admit that the type of individual initiative permitted in an organization is quite different from that which is possible when a person is not a member of an organization. If he wishes to identify himself with a group and wishes to contribute his activities with those who are members of the group, he must then restrict his activities to certain limits and realize that he is contributing to the accomplishment of a group objective, rather than bringing about a complete result himself.

Someone has said that your individual liberty stops where my nose begins. In other words, a person can be more productive within certain established limits than he can be if he is spread all over the lot. If he can concentrate on a particular problem or group of problems, he can contribute a great deal more than if he looks around and makes his own selection and then scatters his effort like buckshot.

ORGANIZATION

Organization has been defined as a body of units, each unit of which has a definite function to perform and all units of which are interdependent. By supplying a few adjectives, we would have the following definition: A good organization is a body of units in which each unit understands and properly performs its functions, and in which all units fully appreciate and accept the interdependence that exists.

Organization implies groups of individuals who are working toward a common objective. It calls for each person's activities to be geared in with the activities of others toward the accomplishment of an over-all result. It requires realization on the part of every member of it that each person or group of persons exists for the organization as a whole rather than that the organization exists for a particular person or group of persons in it.

Organization structure is for the purpose of making an organization function as it should. Organization structure is the medium by which individuals work together in groups as effectively as they would work alone. In fact, membership in an organization should make it possible for an individual to render a greater service than he or she could render alone.

In order for an organization to operate successfully, its structure should be such that it can be understood by every person in it, and its soundness can be quickly interpreted by anyone. If there is any misunderstanding, any confliction of interest, duplication of effort, omission of responsibility, then friction, jealousies, politics, lost time, misdirected effort result, and these defeat the very purpose of organization itself.

Successful administration requires sound organization as well as a simple understandable organization structure. "We in the army get to know, because it is beaten into us from the time we go to West Point, that results with large numbers of people can only be obtained through organization. By organization I mean that chain of understanding that extends from the person who has the top responsibility down to the man on the job."[2]

POWER OF ORGANIZATION THINKING AND EXPERIENCE

Any executive or supervisor who does not establish definite channels, and who does not follow certain practices which will make available to him the constructive thinking of his entire organization, is missing one of the most powerful elements of successful administration. Thomas A. Edison once said, "The greatest power in the world is the unused capacity of the brain."

In any organization there are years of varied and valuable experience. There are minds that are capable of contributing to company policy and to the improvement in company practices and procedures. The successful executive or supervisor acts as a sponge in absorbing the suggestions and thinking of his associates, and as a cream separator in properly evaluating and making full use of them. The more successful he is in providing channels by which thoughts and suggestions can be brought to him unimpeded, the greater is his source of assistance and the bigger he becomes in his own thinking and ability, because of the amount and quality of ideas coming to his attention.

Sir Nevile Henderson, British Ambassador to Germany be-

[2] "WPA—Its Immediate Future," by Col. F. C. Harrington, Fifth General Meeting of WPA Executives, New York City, February 25, 1939.

fore the war, rendered a report dated September 20, 1939, which was quoted in part by the New York *Herald Tribune:* "Nazism, Henderson says, is 'an all-embracing Moloch' and the tragedy of Adolf Hitler is 'that as he goes on, his entourage steadily and inexorably deteriorates. From lack of freedom of utterance he loses the services of his best men. All opposition becomes intolerable to him. All those, therefore, who are bold enough to express opinions contrary to his views are shed one by one and he is, in the end, surrounded by mere yes men, whose flattery and counsels are alone endurable to him.' "[3] In other words, Mr. Henderson is telling us that a person who becomes all-sufficient unto himself, who recognizes no power greater than himself, ultimately deteriorates and dries up. No individual has within himself sufficient knowledge and experience continually to feed his organization while starving himself.

There may be no one person in an organization who is as capable, or as sound a thinker, as the chief, but the combined thinking of the entire organization is usually sounder and more constructive than that of any individual in it.

This is the very heart of what is known as "consultative supervision." It means that the supervisor shares his problems with his subordinates instead of struggling with a problem alone and then presenting what he considers to be a sound solution. The manager who believes in consultative supervision will seek the full counsel of his associates in arriving at the decision.

A decision so arrived at will be completely understood by those who have contributed to it. The necessity of explanation and continuing clarification is eliminated. The process itself is an extremely educational one.

If these conclusions are correct, then any person responsible for setting up an organization structure should be careful to see that it is established in a way that will permit and encourage the free flow of exchange of experience and thinking from the bottom of an organization to the top and from the top to the bottom.

This probably explains what many executives mean when they say that their policies are written from the bottom up. What they are saying is that the entire organization concerned contributes to the formation of policy before the established policy is announced. Those who have practiced this method assure us that policies so formed are far more sound, complete, and workable than those which are formed entirely at the top and sent out as instructions to be followed.

A well-known situation in which the management has fully appreciated the contributions that an organization can make to company policies and practices is that of McCormick & Company in Baltimore, Maryland. C. P. McCormick, president of this company, is the originator of the "multiple-management plan," which incorporates the use of junior boards and junior committees from the top to the bottom of the organization. Multiple management is the medium which Mr. McCormick has set up in order to make full use of the power of the thinking and experience of the people in his company.

Arthur Van Vlissingen, in writing about the McCormick method, states: "After fifteen years or so around a shop where everybody was muscle-bound from holding back, he resolved to give subordinates a chance to use their strength in pushing the business ahead, instead of in repressing their enthusiasm." Mr. Van Vlissingen goes on to say, "Lacking any feeling that he himself knew all the answers, ... he saw plenty of room for doing things better, if only he could enlist the assistance of the folks down through the organization."[4]

[3] New York *Herald Tribune*, Oct. 18, 1939, p. 7.

[4] "One Way to Share the Load," by Arthur Van Vlissingen, *Forbes*, July 15, 1939.

The research man has a formula which guides him in his approach to a particular problem. The mechanic has a plan by which he inspects his machines. The doctor follows a certain routine in diagnosing an illness. A manager should have some kind of a simple formula which he can follow in approaching his job of administration.

MANAGEMENT FORMULA

An executive group was recently discussing a situation which all agreed was true; and that is, that if someone is sent out to investigate certain technical procedures and practices, he comes back with a comprehensive report, clearly defining what he has found to be true. On the other hand, if someone is delegated the responsibility of studying current administrative practices, the report he renders is not very comprehensive or clear-cut as to just what he discovered. The conclusion of the group seemed to be that the reason for this is that, in connection with definite technical activities, there are established commonly understood terms. There are principles which establish mutual understanding. There is a particular vocabulary which can be interpreted by all who are engaged in that activity. On the other hand, this is not true of management. Terminologies vary. There is great differentiation in practices. There is not even agreement on basic principles, and yet, management is probably one of the oldest of professions.

In an attempt to establish a common ground of understanding to get at a basis for mutual discussions, several organizations have developed a simple formula of management. There is a procedure which, if followed, step by step, means successful administration.

The formula itself has remained the same for many years. The methods by which it is applied differ considerably. However, the formula has brought about a common vocabulary of terms of management and has established a basis upon which methods and techniques might be discussed. The formula is as follows:

1 *Organization Clarification.* The activities that must be performed should be carefully and clearly determined. These activities should be divided into organization units and individual position descriptions should result. This means that every person in the organization will know exactly what he is supposed to do, the extent to which he is to do it, and when he is expected to do it. The activities of each person will then be definitely related to each major activity and his work can be evaluated according to the contribution that it makes to the accomplishment of the major activities.

This particular step is sometimes known as "job analysis." Whatever you may call it, it is clarifying the entire organization in writing and making it perfectly possible for any person to know where he fits in the entire picture and to appreciate the part that he plays in it.

2 *Standards of Performance.* The conditions that will result if these activities are performed properly should be determined. A manager, supervisor, or foreman should have definite objectives for the activities which he is supervising. He should know what constitutes a job well done. He should reduce to writing for each activity conditions that will result if the work is done as it should be done.

This is often called "standards of performance." It simply means that each employee will know what constitutes satisfactory performance and can "be pleased with himself when he goes home at the day's end." There is no greater morale builder than the appreciation on the part of a person that he has done what he has been expected to do and he has done it well. If his superiors do not know what constitutes good performance, surely an employee cannot be expected to know it.

3 *Individual Analysis.* Present performance should be periodically compared with the standards that have been established as good performance. A manager should continually take stock of the progress that his people are making. If he has established standards of performance, he has an objective or a goal with which to compare what is

actually being done. As is said in the army, he has an objective and is constantly driving toward it.

This is sometimes called "rating," "indivdiual analysis," or the like. It means that each person under supervision will know from time to time exactly where he stands in the eyes of management. Every employee has the right to know how well he is doing his job, where his weaknesses are, and what his opportunity for improvement is. He should get such information from his immediate superior, and that superior cannot indulge in generalities. He must be specific and to the point.

In discussing this particular phase of the formula, we are not talking about individual characteristics, but we are emphasizing actual performance on the job. If the employee is doing his work satisfactorily, his personal characteristics must be all right for the job. If he is not doing it satisfactorily, then further investigation should be made as to any personal liabilities he may have.

4 *Help and Information Required.* There should be a careful determination of help and information required to correct individual as well as group weakness in performance. Having carefully determined the job to be done, how well it should be done, and how well it is being done the manager or supervisor is in an excellent position to tabulate what training or education is needed. The weaknesses have been indicated. The best judgment of the executive involved is now required to determine remedies.

This particular phase of the formula provides each employee with a definite program of individual development, so that he may perform more satisfactorily and do it willingly. He is conscious of the fact that his management is trying its best to improve him as an individual and to make him of greater value to society. This is where the real function of management comes to the front. A leader is actually measured by the extent to which he develops those who are under his direction. This is a morale builder if there ever was one, and better morale means greater productiveness.

5 *Source.* The best source should be selected from which required help and information can be secured. There is not an employee on our pay rolls who is not entitled to the finest it is possible for us to secure. If it has been accurately determined what the employees need, that same sound judgment can be effectively applied to the selection of proper places from which to get it. The boss himself should be in a position to supply a great deal of it. If he can't, there may be specialists in the organization. If there are no such specialists in the organization, there are those who are available outside the organization who may be brought in or to whom employees may be sent.

If the help comes from the best possible source, the recipients thereof will personally notice improvement in their own knowledge, habits, skills, and attitudes. This means greater confidence—greater morale. It makes a better man and a better citizen. It means better management.

6 *Time Schedule.* A definite time should be established for supplying the needed help and information. If all of the steps of this formula have been applied up to this point and a definite time is not arranged for supplying what is needed, much is to be lost. Here again is where the importance of planning enters into the picture. Time does not just become available. It has to be made available. When particular periods are set aside for required training and development, the organization soon adjusts itself, so that no inconvenience is created.

It is rather self-apparent in analyzing the formula just presented as a guide that it is all directed toward giving full consideration to the human factor in industry. The successful application of any one of the foregoing steps means a better psychological situation in which the employee has to perform his functions. Certainly it means more productiveness; it means greater efficiency; but it is most important to remember in its application that efficiency in itself is an evil, but as a by-product of good morale it is a just reward. It would seem that any administration that would bring about such a result must be classified as sound.

THE HUMAN FACTOR

In considering the profession of management, one basic viewpoint at least seems essential to success. That is the absolute, sincere, and deep-moving conviction that management is the development of people and not the direction of things. Every policy that is written, every plan that is developed, every decision that is made, every activity that is initiated must be considered in terms of the capacity of people to make them successful and the ability of supervisors to inspire on the part of people the desire to produce to their greatest capacity.

It has been said that the executive function is to establish objectives, to determine how far present performance is from objectives, and to discover ways and means of closing the gap between actual practice and what is desired. In reality, that means that the basic function of a manager is to determine what people should, can, and will do; to analyze the actions of people so as to be able to know what they are doing; and to develop and promote plans which will prepare and inspire people to do better than they are now doing.

If this is true, it reemphasizes the necessity for human understanding on the part of the administrator. Organizations must be constructed not as machines but as living elements of human activity. Administrative organization should provide situations in which people can work without friction, misunderstandings, jealousies, and politics. Any organization should be so set up and directed that each person feels that it is a complete outlet for the productive and creative possibilities that lie within him.

The easiest way to get somebody to be what you want him to be is to treat him as though he were what you would like to have him. If you want a baby to talk baby talk, then talk baby talk to him, but if you want him to talk English, then talk to him as you talk to others who speak English. If you wish a worker to have a broader interest in the activities of the organization, then discuss those activities with him as though he had that interest.

The huge administrative machines of the world are human machines. If you want to see the machines fall apart, take the human element out of them. If you wish to see those machines accomplish the highest possible purposes to humanity, then develop the human beings that are in them.

SUMMARY

In the consideration of this subject of administrative organization, we have endeavored to point out that there is a steadily growing realization that administration is a profession and, as such, should be carefully studied by those who practice it. The growing realization of its importance is shown by the increasing study of the subject by industrial and business executives.

The studies that are being made by industrial and business executives have brought out certain conclusions in the form of basic principles that seem to be sound. Administration, as such, has been clarified. Its basic factors are better understood and definite and well-organized programs are being introduced so that executives and supervisors may better practice sound administration.

We have presented a management formula which gives a clue as to what is being done in order to bring about administrative organization. If it is the will of the Society, the Subcommittee on Administrative Organization will continue to function in the hope of developing further studies that might be of value in continued thought on this particular subject.

FIG. 1 PLANE DEMONSTRATING HOW AIR MAIL IS PICKED UP AND DELIVERED IN FLIGHT

AIR PICKUP OPERATIONS

By JAMES G. RAY

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THE record is not clear as to exactly when the first pickup in flight was made or what method was used. However, the files in the Patent Office in Washington disclose that the first pickup device was patented not long after Orville Wright made his amazing flight of 45 mph for the Army in 1908. Thus the idea was born almost with flying itself.

Some impetus was given to the scheme for picking up light loads such as messages and maps during the first World War. Pioneer work was done during that period by Godfrey Cabot of Boston while serving in the United States Navy and, subsequently, he succeeded in developing a device based on the catapult principle which was successfully tested, pickups being made from the tops of buildings.

Seizing on the possibilities of the pickup idea, endurance fliers of that period, the cinema, stunt fliers, and others developed various schemes, none of which contributed particularly to the practical solution of the pickup problem. Somewhat later Dr. Lytle S. Adams, recognizing the potential commercial and military value of the idea, devised a system using a V-shaped apparatus for his ground equipment through which a pickup cable and grapple trailing from the plane were guided. As contact was made the delivery bag slid down the apron of the ground apparatus while the hook passed through its apex, where it engaged the outgoing bag. This system was successfully demonstrated at the World's Fair in Chicago for an entire summer where it was used in picking up air mail daily from a station in a congested area of the Fair grounds. However, Dr. Adams later abandoned this method in favor of a simpler ground arrangement wherein the pickup burden was suspended between two poles.

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MAIL AND EXPRESS PICKUP SYSTEM NEEDED TO EXTEND AIR-TRANSPORT SERVICE

Throughout the period of evolution of air transportation, because of the superior speed of the airplane and the requirement for elaborate and expensive airport facilities, the trend has been to limit service largely to metropolitan centers. Literally, thousands of communities in urgent need of air service are excluded from the air-transport system because of their size, location, or lack of adequate landing fields. Therefore, there is a distinct need for a method by which direct air service may be provided on high-speed schedules over short routes to a number of cities located close together. It is in meeting this need that the pickup principle has found practical application.

The air pickup system now in daily use on two air-mail routes, which were established by the Post Office Department pursuant to a special Act of Congress, authorizing a test of this type of operation in the collection and dispatch of air mail, has been developed by All American Aviation, Inc., which was formed in the latter part of 1938 for the purpose of organizing a system for actual operation with such available methods as

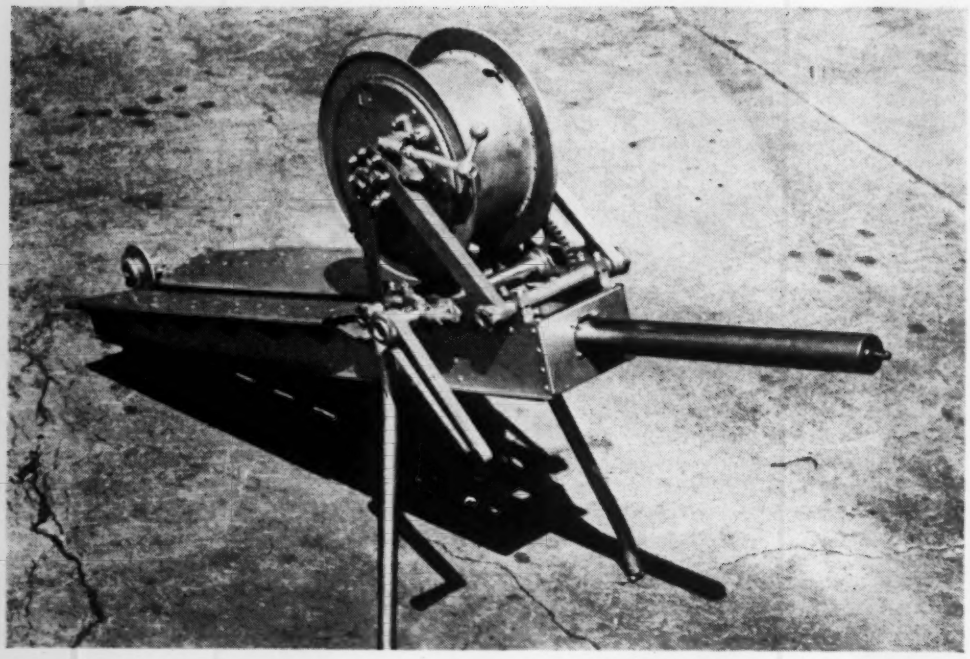

FIG. 2 AIRPLANE PICKUP DEVICE, SHOWING WINCH FOR REELING PICKUP CABLE AND AIR-OIL SHOCK ABSORBER

appeared practicable. In this system, the principles of Adams and Cabot have been embodied as well as the ideas of others and also some entirely new ones. The combination has produced a system which has just completed nearly 7 months of operation, during which more than 13,000 pickups have been made in nearly 300,000 miles of scheduled flying, representing a performance record of 96 per cent. Where pickups were lost, it was usually due to weather which prevented flying rather than failure of the equipment to function. Indicative of further efficiency is the fact that schedules have been stepped up from an average speed of 100 to 110 mph, at which they are now being maintained on both routes.

Simplicity and economy, consistent with safety, have been the important considerations in the development of the air pickup. The fact that a ground station used in the present system can be installed and fully equipped at a cost of less than $200, and can be placed in readiness for operation in less than 1 min, attests to its simplicity and inexpensiveness. The same may be said for the pickup mechanism in the plane. This unit is easily operated and costs less than $2000.

EQUIPMENT AND OPERATION OF PICKUP SYSTEM

The ground equipment, Fig. 1, of the pickup system consists of two steel poles 30 ft high which are topped by a 10-ft wooden flag or marker, a brilliant orange in color. These masts are set in concrete 60 ft apart. A transfer rope to which the pickup bag or container is attached is suspended horizontally between the poles just below the flags, the container resting in the center. These containers are used for both deliveries and pickups.

In its pickup operation, the author's company uses a single-motor Stinson *Reliant*, a standard 4-passenger plane from which all but the pilot's seat have been removed to make room for the installation of the pickup gear, mail bins, and a special seat in the rear for the pickup operator, the second man in the plane. The pickup mechanism consists of a manually operated winch, Fig. 2, provided with suitable brake and ratchet controls, and an air-oil shock absorber held in place by a special mounting. The shock-absorbing unit is designed to carry up to 100 lb air pressure at maximum. Operating pressure is carried at 45 lb. The stroke of the unit is 24 in. This unit absorbs only a small percentage of the impact load, but it is necessary to avoid snapping the pickup cable and imposing excessive strain on the plane. To this mechanism is attached a steel pickup cable 55 ft long having a 4-fingered grapple, Fig. 3, weighing 8 lb at its lower end.

As the plane approaches the air station for a pickup and delivery, the cable and hook are unreeled through a hatch in the bottom of the ship. The rope bearing the delivery container is attached to a release just over the hatch and is lowered by hand, so that, coming into the station, the plane is trailing two lines, the delivery rope being back of the cable. The lines are prevented from fouling by their weight-drag ratios.

To make the contact, the plane comes into the station on a gentle glide much the same as it would in making a landing except that it is maintaining a higher air speed. An instant before the station is reached, the pilot releases the delivery container and rope which fall to the ground. The container, Fig. 4, which has a capacity of 60 lb, was designed especially to withstand the heavy impact of being dropped from a height of 20 to 100 ft from an airplane traveling 100 to 120 mph without damaging it or its contents. It is constructed with a hard-fiber nose and a rubber skirt riveted inside of the nose. A canvas bag is suspended inside this assembly. The air mail itself is placed in small pouches which also have been especially designed for this service and which are in turn put in the bag for pickups and deliveries. In making the pickup, the plane passes over the masts of the air station at an altitude of 50 to 70 ft, with the cable trailing the grapple about 10 to 25 ft above the ground when it strikes the transfer rope. As contact is made, the rope slips down the cable into the grapple. Simultaneously, the bag slides toward one end of the rope on a special fitting, which exerts a frictional resistance causing the burden to be accelerated to airplane speed. Any additional shock occurring is taken up by the air-oil shock absorber in the plane, so that the contact is barely noticeable. Should the cable become fouled by an obstacle on the ground subjecting it to an abnormal strain, a safety link placed just under the fuselage will break, preventing an overload to the plane's structure.

In present operations, the pickup load has been limited to 25 lb but, in tests, loads weighing over 70 lb have been picked up with the same equipment without placing any undue stress

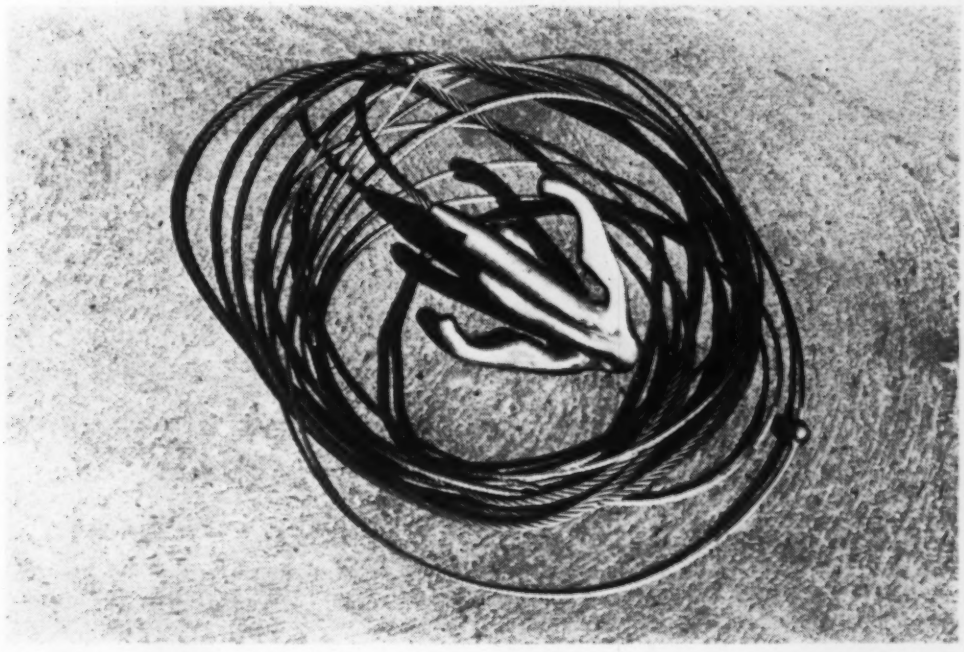

FIG. 3 GRAPPLE WITH WHICH AIR PICKUPS ARE MADE

on the plane, or giving any indication that the limit of load had been reached. The normal speed at which the plane is traveling when pickups are made is between 90 and 110 mph, but they have been successfully made at speeds up to 125 mph. Similarly, there have been no indications that a limit has been reached on the speed at which pickups can be made with present equipment. The gear can be designed to accommodate heavier loads or higher speeds or both, and to fit any type of aircraft.

PROBLEMS ENCOUNTERED IN DESIGNING PICKUP GEAR

The chief engineering problem involved in the design of the present pickup gear for practical operation was to provide for adequate energy absorption to accelerate the burden to the speed of the airplane. Present-day airplanes, flying in the vicinity of the ground, should not be slowed down much below 100 mph. While traveling at this speed, it is difficult suddenly to engage a mass that is stationary. The accelerating impulse must be applied to this mass over an interval of time, in order to bring it up to the speed of the airplane without creating excessive loads in the engaging member.

Both Adams and Cabot used the catapult principle in meeting this problem. Adams also developed the plan for absorbing the shock through a device provided in the plane to which the pickup member is attached, and this idea is embodied in the air-oil strut that is used in the present system. This strut has a travel of some 30 in., but used alone would not suffice in picking up any substantial burden of mail and express, and therefore additional energy-absorption means were necessary.

A simple invention supplied the solution to this problem, although finding it was not so easy. This invention consists of the slide-fitting unit by which the pickup container is attached to the transfer rope. This fitting is an energy-absorbing device which slides gradually along the rope during a pickup, allowing the burden as much as 30 ft in which to accelerate. It is evident that it would be almost impossible to attain a 30-ft travel by any other shock-absorbing means attached to the airplane.

As a natural step in its development, the pickup system has been recently adapted to night operation, and pickups are now being made nightly at three stations on the western end of the Philadelphia-Pittsburgh route to test its practicability. As the greatest volume of mail moves at night, the adaptation of the system to night operation obviously will increase tremendously the value and scope of the air pickup as a method of transportation and communication.

NIGHT-FLYING PICKUP EQUIPMENT

Like the rest of the system, the night-flying equipment which has been developed is simple, economical, and easily installed and operated. The air station is lighted by outlining the flag on the top of each mast of the station with a ribbon of red neon.

The approach to a pickup station is customarily made at a gliding angle of 7 to 1, which is the normal glide path of the Stinson in still air with the added resistance of the trailing pickup cable and delivery line. A range light has been placed along the flight path beyond the lighted marker at the proper distance to give the flyer this angle to guide his approach. This range light is a single 12-ft horizontal bar of red neon. Pilots report that the lighted stations under normal conditions can be seen plainly from the air at a distance of 6 miles which is farther than they can be seen in daylight, and that the pickups are made as easily at night as by day.

The principal advantages of the pickup system developed by All American Aviation over previous systems can be enumerated as follows: It makes possible the picking up of heavier loads; the pickup can be made at higher speeds; the cost of the gear and its maintenance is low enough to make the operation practical; and it can function with the same facility at night.

So far the air pickup system has been installed in planes carrying mail and express. There appears to be no reason why it cannot be installed in larger passenger-carrying planes to enable them to pick up mail and express at points where landings for passengers are unnecessary. As a matter of fact, its use in this fashion seems inevitable if small communities located close together are to have passenger, as well as air-mail and air-express service, because a schedule requiring a stop at every point would be entirely too slow to be practical.

In adapting the pickup system to passenger-carrying planes, it would be desirable to use multimotored equipment. Because these planes would operate on relatively small airports, their

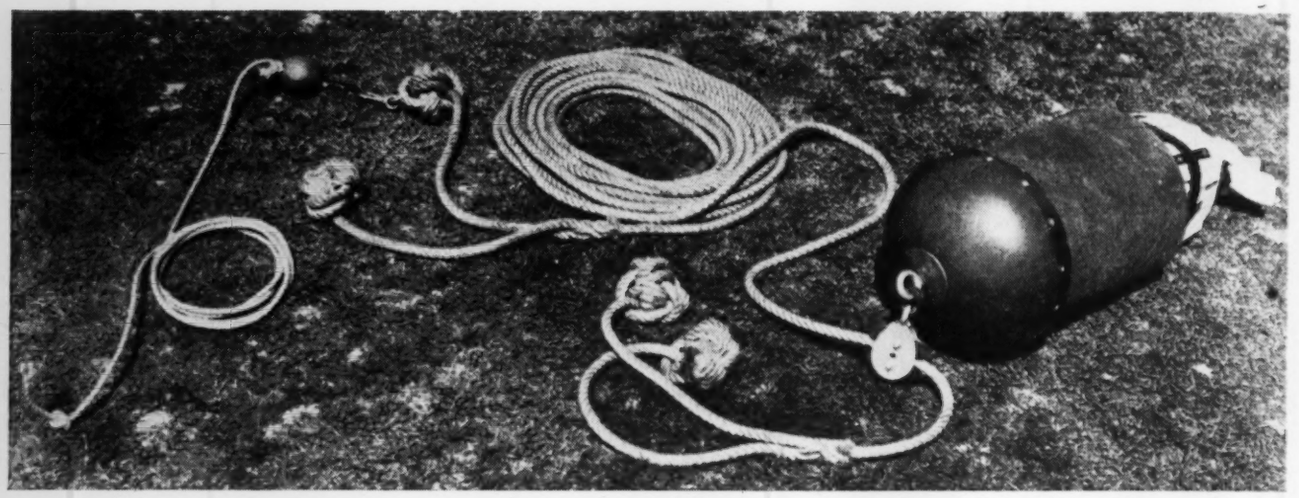

FIG. 4 AIR PICKUP TRANSFER EQUIPMENT SHOWING TRANSFER ROPE, CONTAINER, AND METHOD OF ATTACHING ROPE TO STATION

size and capacity would have natural limits. A dual-engined airplane capable of carrying a crew of 2 and from 4 to 6 passengers and having a cruising speed of about 150 mph, would be admirably suited to this type of service. Flights have been made over a part of the pickup routes in small multiengined planes of the type described, in which pickup operations have been simulated. In each instance, these planes have carried a number of passengers, and none spoke of feeling any mental or physical discomfort in flying down over the pickup stations. Certainly, the pickup operation is less disturbing to the passenger, and is safer than making a landing, because the plane never closely approaches its stalling speed, and is consequently always under excellent control.

Beyond the orbit of the airways, in what might be called the twilight zone of our air-transportation system, are thousands of small but, nevertheless, important and progressive cities which are anxiously seeking direct air service. Established air routes now serve slightly over one fourth of the population of the country. Of the 4000 or more cities in the United States with more than 5000 inhabitants, there are only 210 cities on the air lines, excluding the 54 cities on the present air-mail-pickup routes operated by All American Aviation, Inc.

The desirability of tapping the potential traffic beyond the airways through feeder lines has been recognized by the aviation industry, but finding a satisfactory plan has been difficult. The innovation of the air pickup has suddenly simplified this problem by presenting an ideal basis for the establishment of air lines radiating from present air-transportation centers which can include practically all of the surrounding cities and towns. Linking these lines together in a national system will provide a network over which mail and express and perhaps passengers can be carried from any point in the country to any other point in less than 24 hr.

Vast opportunities for the development of aviation have been created by the air pickup. For the industry, it will mean a new market for its aircraft and its equipment, and more employment. By providing a large reservoir of trained personnel it will be making a valuable contribution to the national defense. Business, industry, and the public generally will share the benefits as it will mean that all will have the tremendous advantages of direct air transportation without paying an extravagant price for the privilege. Operation of the present air-mail-pickup routes clearly indicates that, in so far as financial support from the government is concerned, such lines will develop sufficient air-mail revenues to make them self-sustaining. It has brought immeasurably nearer the day when air transport will be able honestly to claim that it is a "public convenience and necessity."

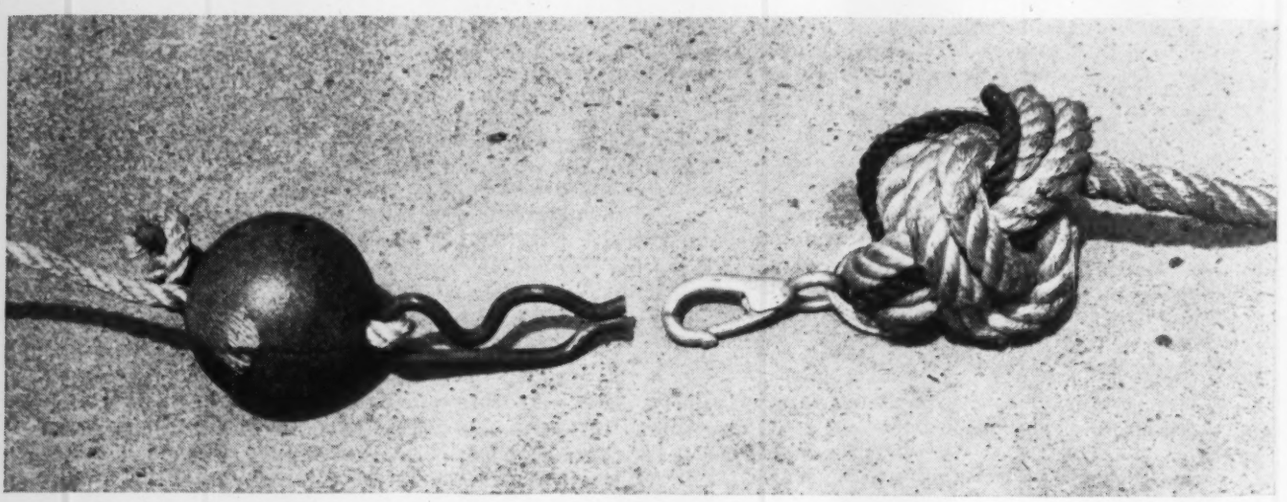

FIG. 5 ARRANGEMENT BY WHICH TRANSFER ROPE IS ATTACHED TO HOISTING LINES ON PICKUP POLES BY SNAP HOOKS CONNECTED TO SPRING CLIP; HOOK PULLS FREE AT 120 LB TENSION

Measuring VELOCITIES *in* DREDGE PIPES

Salt-Velocity Method Applied to Pipe Lines Transporting Solids

By GEORGE W. HOWARD

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METHODS used for determining velocities in dredge pipes have always been subject to criticism because of obvious errors resulting from the manner in which material is transported in the pipe. The velocity tests to be described are believed to be the most accurate which have been made under conditions wherein the discharge line was carrying a large percentage of solids.

In dredging operations along the coast, it is possible to measure the amount of material moved by surveys made before and after dredging. The material remains in place and actual yardage is obtained readily by these place measurements. The velocity in the pipe line, then, is not of such importance as is this same factor in the discharge lines of dredges spoiling into streams with an appreciable velocity. This fact has led to the common use of the "velocity stick," illustrated in Fig. 1, for the determination of pipe-line velocities for dredges operating along the coast. The velocity stick, while not indicating an accurate velocity, is sufficient for the general needs.

Determination of pipe-line velocities for channel-maintenance dredges, which, for example, discharge into the Mississippi River, is a more difficult operation. In this case, the accurate measure of pipe-line velocity is of greater value due to the fact that such information, combined with the determination of the concentration of solids, permits a check to be made on the surveys before and after dredging. The fact that, at times, the water into which the spoil is discharged has an appreciable velocity, makes this procedure desirable.

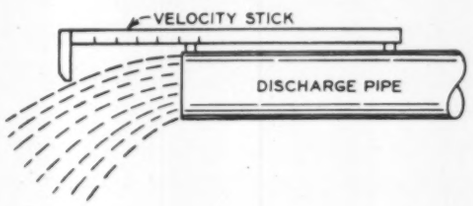

FIG. 1 USE OF VELOCITY STICK

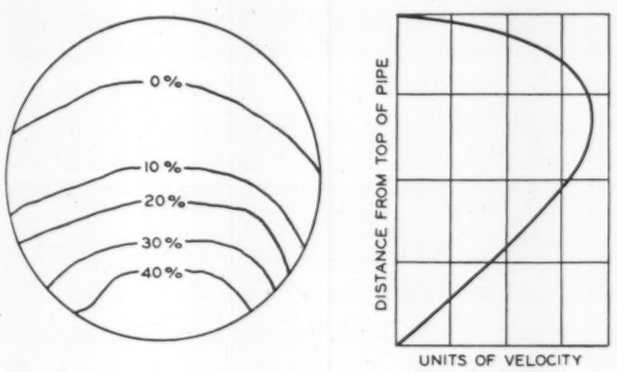

FIG. 2 SOLIDS AND VELOCITY DISTRIBUTION
(Inside of dredge pipe, schematic.)

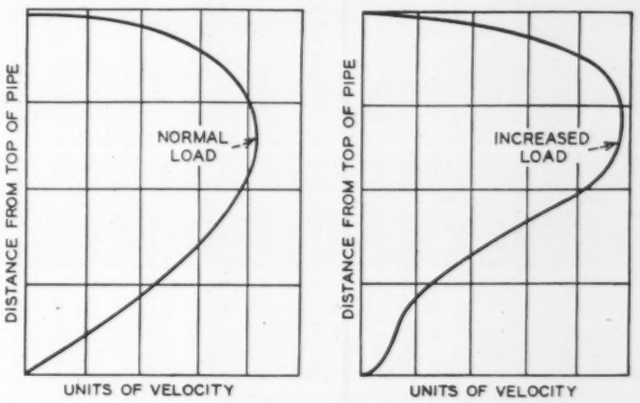

FIG. 3 CHANGE IN VELOCITY DISTRIBUTION FOR INCREASED LOAD, SCHEMATIC

The salt-velocity method is the one generally accepted by which pipe-line velocities may be determined other than that of the velocity stick. The procedure was originated by Professor C. M. Allen of Worcester Polytechnic Institute, and has been proved satisfactory and highly acceptable for determination of flow in dredge pipes carrying clear water,[1] as has been demonstrated in tests on the West Coast.[2] Under certain circumstances, however, the salt-velocity method is objectionable to dredging practice.

OBJECTIONS TO SALT-VELOCITY METHOD FOR PIPES TRANSPORTING MATERIAL

Low-powered dredges, or dredges with long discharge lines, often have low pipe-line velocities at which material will tend to settle out along the bottom of the pipe. Such settlement of material causes solid concentrations as shown in Fig. 2. Under these conditions the salt solution, introduced at the dredging pump and measured at terminals located in the top of the pipe, cannot be expected to yield satisfactory results. A further disadvantage lies in the fact that, as the line is loaded and the concentration is increased, more sand tends to settle out on the bottom of the pipe with a resultant decrease in average velocity. However, this causes an apparent increase in the average pipe-line velocity as determined by the salt-velocity method. Fig. 3 illustrates the statement that the velocity is affected by an increase in solid concentration.

[1] "The Salt-Velocity Method of Water Measurement," by C. M. Allen and E. A. Taylor, Trans. A.S.M.E., vol. 45, 1923, pp. 285–341.

[2] "Friction in Dredge Pipes," by J. H. Polhemus and J. R. DuPriest, Trans. A.S.M.E., vol. 49–50, 1927–1928, paper HYD-50-7, pp. 17–22.

TESTS CONDUCTED USING SALT-VELOCITY METHOD

That the salt-velocity method can be applied with satisfactory accuracy when material is transported in a pipe was successfully demonstrated during tests conducted in 1936 on a Mississippi River dredge operating just north of Memphis, Tenn. The dredge *Jadwin* is occupied normally in channel-maintenance work at crossings. It has a dustpan suction head with a 34-in. suction pipe and a 32-in. floating discharge pipe. Velocity observations by means of the salt-velocity method were made in connection with tests to determine the relative capacities of plain and rifled discharge pipe.

Fig. 4 shows the arrangement of the apparatus for velocity

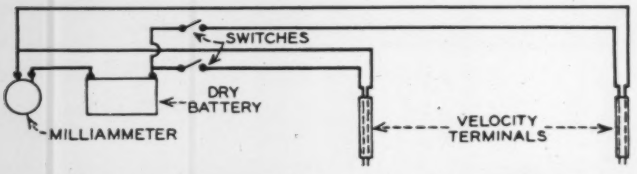

FIG. 4 WIRING DIAGRAM FOR OBSERVATION OF PIPE-LINE VELOCITIES

observations. The salt solution was introduced into the suction side of the pump. The dredge was equipped with interchangeable discharge lines, one plain and one rifled. In order that the limiting conditions would not be the dredge itself but rather the discharge lines, the discharge pipe on the dredge was equipped with rifles. At the completion of each test, the floating line was changed and pumping resumed through a different floating discharge line. Solid concentrations were determined by means of a Conrath solids gage, a development of the United States Engineer Office, Memphis, Tenn. By means of this gage an instantaneous sample of the solid concentration may be obtained close to the pump, where all material is in suspension.

Observations of both solid concentration and velocity were made every 5 min. Additional observations were made at 15-min intervals by means of instruments, which included (1) the operating room, suction and discharge gages of the dredging pump, and the discharge gage of the jet pump; (2) the pump room, suction and discharge gages of the dredging pump, the dredging-pump tachometer, the condenser vacuum and steam-pressure gages, the steam-temperature thermometer, and the high-pressure steam flowmeter; (3) the boiler room, feedwater flowmeter, and fuel-oil gages.

RESULTS OF SALT-VELOCITY TESTS

Results pertinent to the use of the salt-velocity method for velocity determinations were obtained during the first 2 days of operation with plain pipe. The velocity terminals were located on the floating line during the first day of operation, and the high velocity obtained from these observations indicated that the values were not accurate. Accordingly, the terminals were located on the dredge 150 ft apart, one immediately below the pump and the other at the stern.

Data obtained during the two tests under identical conditions are shown in Table 1. The only difference in the two tests lay in the fact that the terminals were located in the floating discharge line in run No. 2 and in the discharge line on board the dredge in run No. 4.

Inspection of Table 1 indicates the great difference in velocity measurement obtained as a result of changing the position of the terminals. The velocity, as determined by observations on the floating line, was 3 ft per sec greater than that obtained from the observations made on the dredge, or a gain of 14 per cent over the velocity obtained under the more advantageous conditions. The high pump efficiency for run No. 2 (89.7 per cent) is a definite indication of error in velocity measurements.

TABLE 1 COMPARISON OF PLAIN PIPE SHOWING RESULTS OF INCORRECT VELOCITY OBSERVATIONS OF RUN NO. 2

Run no.	2	4
Location of electrodes	Discharge line	Dredge
Pump speed, rpm	175	175
Effective time, hr	3.17	5.50
Solids, per cent, average	21.4	18.2
Velocity, ft per sec	24.8	21.8
Yards per hour (solids × velocity × pipe area = cu yd)	3954	2994
Water horsepower	1211	1015
Shaft horsepower (turbine)	1350	1520
Pump efficiency, per cent	89.7	66.8

The 66 velocity observations, which entered into the 5.5-hr average of 21.8 ft per sec, are believed to be more nearly accurate than any previously obtained by means of the salt-velocity method applied to pipe-line dredges, in which the discharge line had a large solid concentration. Admittedly these results are not absolutely accurate, because of the variation in concentrations which occur; nevertheless, it is believed that the tests were made under more uniform conditions of flow through the discharge line than were any other previous tests of this type. The variation of the material over the pipe was fairly uniform, because of the effects of the rifles. This fact has been pointed out by Gladfelter[3] and is supported by data obtained during the tests. Fig. 5 shows the type of solid concentration obtained.

FIG. 5 TYPE OF SOLID CONCENTRATION OBTAINED DURING TESTS[3]

CONCLUSIONS

1 The salt-velocity method is not suitable for dredges pumping material which settles on the bottom of the pipe unless some means is used to keep the material evenly distributed over the cross section of the pipe between electrodes.

2 Observations, using the salt-velocity method in a plain pipe, result in apparent increases in velocity as the line is loaded.

ACKNOWLEDGMENT

The tests described were conducted by the United States Engineer Office, Memphis, Tenn., of which Colonel Eugene Reybold was then district engineer. H. S. Gladfelter, senior engineer, was in general charge of the tests, which were under the direct supervision of R. Y. Newell, Jr., assistant engineer. The author, representing the U. S. Waterways Experiment Station, Vicksburg, Miss., served as observer and consultant during the tests.

[3] "Transportation of Sand and Gravel in a 4-In. Pipe," by George W. Howard, discussion by H. S. Gladfelter, Proceedings of the American Society of Civil Engineers, vol. 65, no. 3, 1939, pp. 460–462.

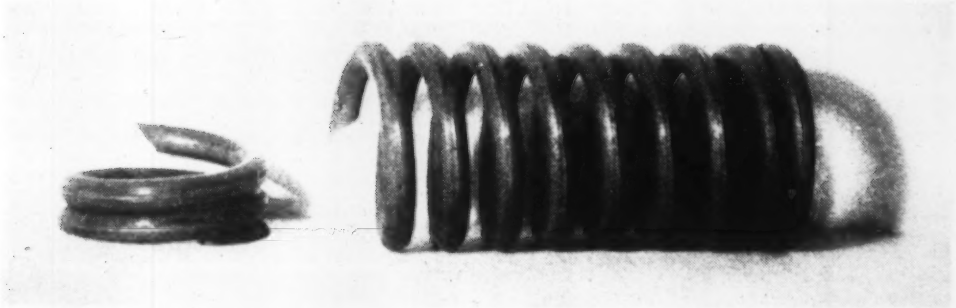

FIG. 1 SPRING SHOWING TYPICAL FATIGUE FAILURE

Factors in the FATIGUE *of* HELICAL SPRINGS

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EVEN though fatigue failures are not a problem in many spring uses, occasionally, in the application of helical springs to various types of mechanisms, failures by fracture are encountered, usually after some considerable period of service. Practically all these failures are cases of progressive fracture, since helical springs are just as susceptible to fatigue phenomena as are other machine parts which have been widely studied. Indeed, helical springs may be more susceptible than other parts, because they are so often designed with little or no factor of safety, and the majority of designs make use of as much of the available elasticity as possible.

The mechanism of spring fatigue parallels other types of fatigue, and many of the theories developed from the vast amount of study already given the subject apply equally well to springs. With this background of experience, therefore, the problem of spring failures becomes a matter of careful consideration of a number of factors peculiar to helical springs. Conversely, proper consideration of these factors, in the design stage, leads to the prevention of fatigue troubles.

ANALYSIS OF TYPICAL SPRING FAILURE FROM FATIGUE

In the following discussion, a typical spring, which has given trouble from fatigue failures, is taken as an example for which the complete analysis of the problem is worked out. This example is a compression spring, made of a pretempered straight carbon steel, to the following specifications:

Dimension specifications

Outside diameter, in.	1.0
Wire diameter, in.	0.148
Free length, in.	$2^{7}/_{16}$
Total coils	$11^{1}/_{2}$
Coils closed, each end	$1^{1}/_{2}$

Ends ground square

Load specifications

40 lb at $2^{1}/_{8}$ in. length
76.5 lb at $1^{27}/_{32}$ in. length

Contributed by the Iron and Steel Division, for presentation at the Spring Meeting, Worcester, Mass., May 1-3, 1940, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Commercial tolerances apply and a stress-relief treatment is given in the course of manufacture. The spring is illustrated in Fig. 1.

Under the topic amount of work expected of the spring, which is the main factor in spring fatigue, the important feature is the stress cycle imposed on the wire, rather than the technical value of the work done. From the load values specified, fiber stress is readily determined from the standard formula

$$S = \frac{8PD}{\pi d^3}$$

in which

S = maximum fiber stress in torsion, lb per sq in.
P = load on spring, lb
D = mean or pitch diam, in.
d = wire diam, in.

This calculation gives a nominal working-stress range from 26,800 to 50,800 lb per sq in. However, an additional factor is the effect of curvature and direct shear, which has been well established by A. M. Wahl. With an index (D/d) of 5.76, the Wahl factor for this spring is 1.26. Multiplying the foregoing stress figures by this factor gives a true stress range from 33,800 to 64,000 lb per sq in.

In order to illustrate and compare these and subsequent stress cycles, use is made of what may be an unusual method of plotting, shown in Fig. 2. In this graph, the ordinate scale represents stress values and, instead of an abscissa scale, an oblique reference line is drawn from the origin to some convenient stress value, depending upon the range it is desired to include in the chart. The value of the minimum stress of the cycle is plotted at the intersection of the stress line and the reference line, and the maximum stress of that cycle is plotted vertically above the minimum point, at its appropriate value. Fig. 2 therefore shows line ① representing the nominal stress cycle, and line ② giving the corrected cycle.

There is another factor which may well influence the stress cycle of the spring, namely, the effect of manufacturing tolerances in spring dimensions. Because of the unavoidable varia-

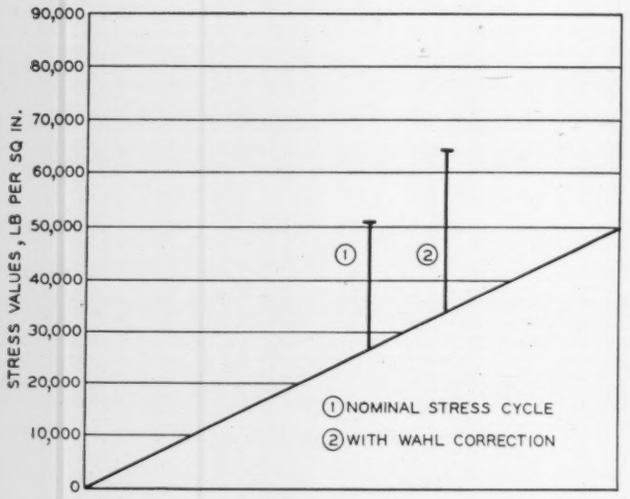

FIG. 2 GRAPHICAL PRESENTATION OF WORKING CYCLE OF SPRING

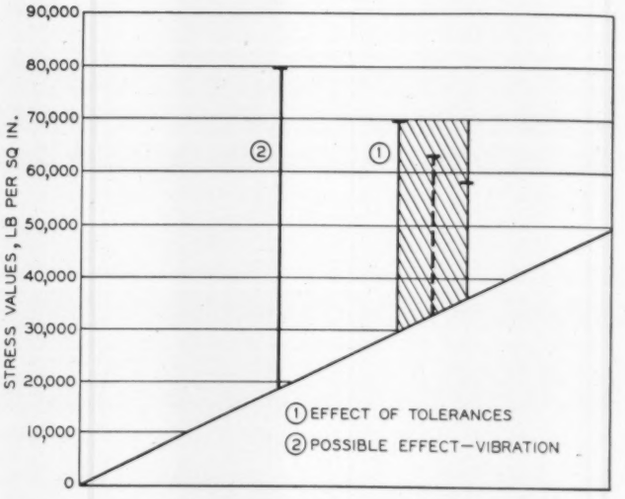

FIG. 3 GRAPH OF VARIATIONS OF WORKING CYCLE

tions encountered in the coiling of helical springs, an over-all commercial tolerance of ±10 per cent must be allowed in the load specification. In this example, this means that the minimum load may be anywhere from 36 to 44 lb, and the maximum from 69 to 84 lb. Therefore, the stress values will vary accordingly, and the least stress value may be (with Wahl correction) 30,100 lb per sq in. and the greatest value 70,300 lb per sq in. Usually, a spring that is weak on one load will also be weak on the second. Hence, the stress range may be from 30,100 to 57,700 lb per sq in. Similarly, a spring on the strong side may have a range from 36,800 to 70,300 lb per sq in., these stresses corresponding to the low and high load values at each specified length. Although not often the case, it is possible that a spring weak on the first load may be strong on the second, or vice versa, due to peculiar variations in length, diameter, and number of coils. The narrowest possible working range is thus from 44 to 69 lb, or 36,800 to 57,700 lb per sq in., and the widest possible range from 36 to 84 lb, or 30,100 to 70,300 lb per sq in. This condition is shown by the shaded area of Fig. 3, indicating that any spring out of a large quantity may have a working-stress range somewhere within this area.

INDUCED VIBRATION OF HELICAL SPRINGS

A factor which is usually neglected in the design of ordinary machine springs is the inherent susceptibility of helical springs to induced vibrations. Den Hartog has referred to this as "subharmonic" vibration, since impulses, acting on the spring at a frequency which is some fraction of the natural frequency of the active spring helix, can set up resonance in the spring and cause vibrations of serious amplitude within this helix. The larger the ratio of natural frequency to impulse frequency, apparently the smaller is the amplitude of the induced vibration. In most cases, when this ratio is 15 or greater, the vibration will not be serious.

In order to study this question, three elements of the mechanism must be known, namely, the speed of operation, the nature of the motion, and the natural frequency of the spring. The speed of operation is the frequency of impulse which may affect the spring. The nature of the motion is important in that, with anything other than a sinusoidal motion, acceleration and deceleration set up inertia forces which play on the elasticity of the helix. Even with sinusoidal motion of the spring and adjacent parts, there may be transmitted to the spring shock from other action of the machine which can have the same effect.

The third consideration, natural frequency of the active helix, lends itself to calculation, although the results are not as accurate as might be desired. Ricardo's formula

$$n = k\sqrt{R/W}$$

in which

n = number of vibrations per min
k = numerical constant
R = spring rate, lb per in.
W = active mass

is widely used in this connection. This equation can be put into a more readily applied form by substituting for R its equivalent from the helical-spring-deflection formula, and for W its equal in terms of spring dimensions. These relations are

$$R = \frac{Gd^4}{8ND^3}$$

and

$$W = \frac{2.67\,\pi d^2\,DN}{144\,g}$$

where

G = modulus of rigidity
N = number of active coils
g = acceleration of gravity, ft per sec per sec

and other symbols as before.

With these substitutions, the equation simplifies to

$$n = k_1\frac{d\sqrt{G}}{ND^2}$$

Values of k_1 have been variously given in the literature and elsewhere ranging from 216 to 250. A series of stroboscopic tests on springs of about the same size as this example has established an approximate value of 246 and, with this as a basis, the natural frequency of the spring under consideration is 19,800 cycles per min.

The possible inaccuracy of the foregoing formula lies in the proper value of the constant, and also in the determination of the number of active coils. This latter value is difficult to measure exactly and is usually taken from the spring when free, though it decreases slightly when the spring is compressed.

In theory, if the frequency of an impulse acting on the spring is an even fraction, such as $^1/_{10}$ of the natural frequency, vibration will occur. Actually, in testing a number of springs, graphical determination of natural frequency shows that the

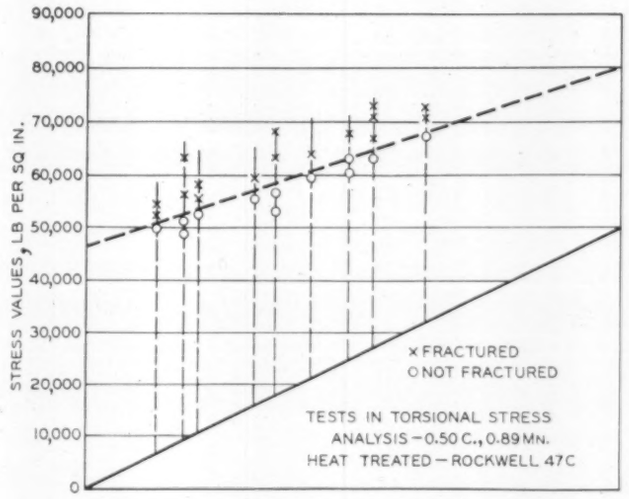

FIG. 4 RESULTS OF FATIGUE TESTS ON SPRINGS

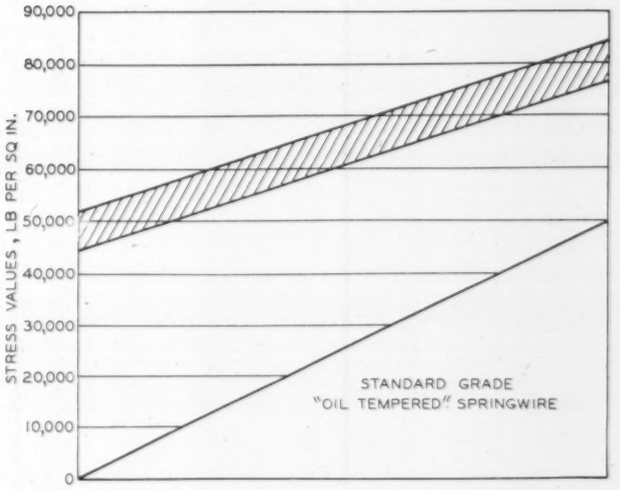

FIG. 5 RANGE OF ENDURANCE LIMIT IN COMMERCIAL OIL-TEMPERED SPRING WIRE: SIZE 0.148 IN.

ratio is often something other than a simple fraction, for example $^1/_{9.82}$. However, it is well established that at various steps in a speed range, there will be points roughly corresponding to $^1/_8$, $^1/_9$, $^1/_{10}$, etc., of the natural frequency, at which resonance will occur. For purposes of the present discussion, it may be assumed that the spring under consideration is operated at a speed of 1800 cycles per min, which is $^1/_{11}$ of the natural frequency. In all probability, this is close enough so that some degree of resonance is established.

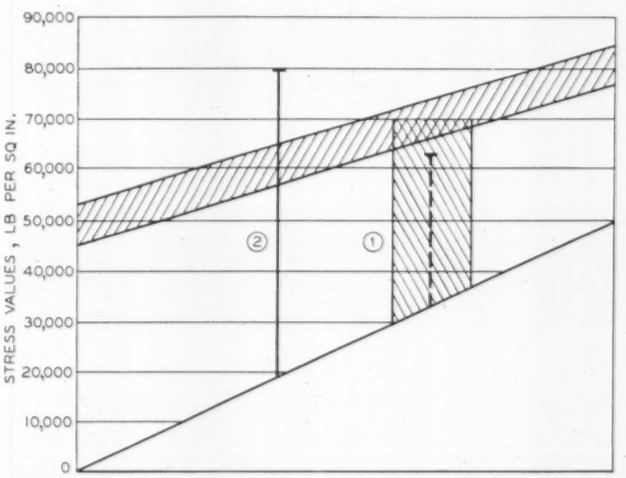

FIG. 6 COMPARISON OF TRUE WORKING CYCLE AND ENDURANCE-LIMIT RANGE

Although somewhat difficult to describe, it is readily seen with a stroboscope that a wave travels from one end of the active wire to the other which causes a momentary displacement of each coil in relation to its adjacent coils. This displacement results in a change in the stress conditions within the three coils. Measurements through the medium of extremely high-speed photography show that it is possible for this displacement (the amplitude of the forced vibration) to become great enough so that adjacent coils touch, or even strike together noticeably, as the wave passes. For some obscure reason, this does not occur at every resonant speed, but it can and does take place in many instances.

It follows from this fact that the spring may receive the equivalent of solid compression under certain conditions. The fiber stress at solid compression is usually considered only in relation to elastic limit but, in the light of the present concept, it becomes the end-point in the stress cycle. Calculation gives a value of 79,300 lb per sq in. for the fiber stress of this spring at solid compression. Consequently, the maximum stress of the cycle under vibration may increase to 79,300 instead of 64,000 lb per sq in., as previously found. Furthermore, if the maximum stress is increased because of the vibration amplitude, which may be called positive, the minimum stress is decreased by an equal negative amplitude. Thus, the stress range is widened markedly under these conditions. This analysis of the vibratory motion and its effect upon the spring is amply supported by high-speed photographic recordings. Therefore, the minimum stress value is decreased by at least 15,300 lb per sq in. and becomes 18,500 lb per sq in. The new stress cycle which the wire of the spring passes through is shown by line ② of Fig. 3, although it cannot be said that the spring works through this cycle, since the spring as a whole does not receive this equivalent in deflection.

In passing, it is well to note that the spring is forced to go through this augmented stress cycle, not at 1800 cycles per min, which is the speed of the mechanism, but 11 times as fast, or 19,800 cycles per min, the natural frequency. This is the explanation for many cases of "short life," or "premature breakage," as measured by time of service.

EFFECT OF PHYSICAL PROPERTIES OF MATERIALS

An important phase of the fatigue problem is always found in the physical properties of the material in question. In the present paper, discussion must be limited to only one of the wide variety of spring materials available, and space is not available to take up all the metallurgical elements which influence the fatigue properties of this one grade of wire. It may be said, however, in summary of a considerable number of investigations, that, in the case of a heat-treated wire, the most important factor seems to be hardness, with minor effects traceable to grain size, analysis, and manufacturing practices.

Just as endurance limits have been established for metals under bending stress (rotating-beam tests, etc.), so spring wires have been tested under torsional stress, and diagrams similar to the "Goodman" type in bending have been established. By means of a number of tests on actual springs, covering a wide range of stress cycles, with carefully controlled stress condi-

tions, points may be plotted as shown in Fig. 4. These tests can readily show endurance limit by differentiating between failure and nonfailure within 5,000,000 to 10,000,000 cycles. A line can be drawn on the graph to mark the differentiation which is then the limiting line for maximum stress in the cycle, and the reference line for plotting becomes the limiting line for minimum stress. It may be noted that plotting in this fashion gives only the useful portion of the complete diagram. Reversed torsional stresses do not need to be considered for helical-spring purposes, and there is no practical use for information concerning stresses above the elastic limit, so that no good purpose is served by establishing the complete diagram.

Again in the present considerations, some manufacturing tolerances in the properties of a wire must be allowed. Commercial wires vary about 20,000 lb per sq in. in ultimate tensile strength, and 3 to 4 points in Rockwell hardness. Therefore, in general discussions of fatigue properties, the endurance limit of a certain grade of wire must be considered, not as a definite line, but rather as an area or band, such as is shown in Fig. 5. This chart is the result of a number of tests on the same grade of commercial wire, samples being taken from various lots made at various times. Consequently, it well covers the variables encountered in manufacturing operations, and is representative of the spread which may be found in the standard product.

COMPARISON OF FATIGUE PROPERTIES OF MATERIAL WITH FATIGUE REQUIREMENTS OF SPRING

The final point toward which this discussion has been leading is a comparison of fatigue properties of the material with the fatigue requirements of the spring. Such a comparison is readily and clearly accomplished by superimposing the chart of Fig. 5 on that of Fig. 3, with the result shown in Fig. 6. Here it is seen that, because of the variation in endurance limit as discussed and the variation of stress cycle due to spring tolerances, there may be some springs which will fail from fatigue, since the stress cycle in some springs may overlap and exceed the endurance limit of some wire. It will also be seen that the planned working cycle, that is, the mean cycle shown within the shaded area of the chart, does not exceed the endurance limit, the point being in this instance that the necessary tolerances throw the stress up into the dangerous area. If the added factor of vibration is present, the effect of tolerances and the planned cycle is submerged, and the forced working cycle is considerably in excess of the endurance limit, indicating certain and rapid fatigue failure.

In summary of the foregoing discussion, it may be stated that the fatigue properties of a helical spring can be established by a comparison of the endurance limit of the material used with the true stress cycle, as determined by design specifications, allowance for curvature and other stress concentrations, and vibration effects. It seems that a large majority of spring failures are accounted for in the true stress values, while there are some, of course, which result from metallurgical factors. Because many springs are designed for limited space, it is not possible to give the allowance for the factors as outlined, which would prevent a large number of spring failures.

In conclusion, it is not the intent of this presentation to imply that all springs need to be analyzed in the foregoing manner. Fatigue is not a factor in many spring applications, but in those troublesome and annoying cases which do occur quite frequently, this outline gives the method by which the trouble may at least be understood, if not eliminated.

LARGE MOLDING FLOOR, NORTH EAST PART OF FALK STEEL FOUNDRY, MILWAUKEE, WIS.

(A visit is planned to the Falk Corporation plant during the A.S.M.E. Semi-Annual Meeting in Milwaukee, Wis., June 17–20. For details see page 340 of this issue.)

The GRAIN SIZE *of* STEEL

An Introduction to the Subject

By J. R. VILELLA

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IT HAS long been known that heats of sound steel, made to the same narrow range of analysis, may differ in their response to heat-treatment and in their properties to a degree not explainable by differences in their nominal chemical composition (C, Mn, Si, S, P, Cr, Ni, etc.). For example, of several heats of the same nominal composition, some may harden superficially and others deeply, when similarly quenched from the same temperature; or some may be able to absorb an impact which will break others even though all had been similarly wrought and heat-treated. These differences, which ten or fifteen years ago were rather mysterious and unpredictable, are today better understood; they have been found to correlate with differences in the grain size produced in the steel at hot-working and heat-treating temperatures. This has led to the commercial production of steels of controlled grain size with uniform response to a given heat-treatment for each type and this control has been of great benefit to all concerned.

In view of the importance attached to the grain size of steel as one factor affecting its quality for certain uses, it is not surprising that engineers, designers, and other users of steel without specialized metallurgical knowledge should feel the need of a clear exposition of the metallurgist's ideas on this subject. While the literature on grain size to date is not so voluminous that an interested person could not locate readily any published information, it is to some extent diluted with discussions of theories and controversial subjects, in many cases expressed in a somewhat ambiguous and loose terminology which tends to confuse the reader.

This article is an attempt to state in the simplest possible terms the most important facts pertaining to the grain size of steel, and to point out the significance, if any, of several qualifying phrases, such as "McQuaid-Ehn grain size," "inherent grain size," "austenite grain size," and "ferrite grain size," these phrases being probably the main source of confusion to the lay reader. Its ultimate purpose is to assist any interested reader in understanding the matter as now seen by the metallurgist.

It must not be forgotten, however, that the mechanical properties of a steel depend not alone on its grain size but also upon the constitution and microstructure of the metal as a whole. A complete discussion of the constitution and microstructure is beyond the scope of this paper. In developing the subject it will be necessary to review briefly the fundamentals of carbon-steel metallurgy, to define a number of indispensable terms, and to emphasize the distinctions by a liberal use of photomicrographs. Since the article is addressed chiefly to those who are not conversant with the underlying principles of metallography and heat-treatment, it is necessarily elementary and of limited scope. It deals entirely with plain carbon steels, though the statements made are generally applicable to the commonly used alloy steels; when a large amount of alloying elements is present, the situation becomes too complex to admit of general statement, except, of course, that the same principles apply.

The general conclusion is that statements relative to grain size are of little significance unless (*a*) the type of grain is specified, there being at least two, and possibly three, types of grains, each of which may exert a characteristic influence on the property of the steel with which we are concerned; (*b*) the precise conditions are specified under which the grain-size determination was made; and (*c*) the observations are properly interpreted on the basis of established metallurgical principles. It is to be emphasized that the properties and behavior of a steel depend fundamentally upon its structure—that is, upon what may be called the mode of occurrence and distribution of the several phases present, particularly the carbide phase in the metal matrix—and that the grain size is only one aspect of the structure as seen under the microscope.

A BRIEF OUTLINE OF CARBON-STEEL METALLOGRAPHY

Ferrite, Iron Carbide, and Austenite. Unhardened plain carbon steel at ordinary temperatures is made up of a matrix or ground mass of comparatively pure iron, known as ferrite, in which is dispersed the carbon content of the steel in the form of minute particles of iron carbide (Fe_3C), sometimes called cementite. In steels which have been normalized,[1] annealed,[2] rolled, or forged, the iron-carbide particles generally are in the form of platelets or lamellae which alternate with ferrite to produce the typical lamellar structure known as pearlite. The spacing of these lamellae is the most important factor controlling the properties of a pearlitic steel. When they are coarse and widely spaced, as in Fig. 1*A*, the steel is soft, ductile, and of low tensile strength; but as the fineness of the lamellae increases, as in Figs. 1*B* and 1*C*, the steel gains hardness and strength but loses ductility. The spacing of the lamellae is a direct result of the rate of cooling through the transformation temperature or range, that is, the faster the steel is cooled within this range, the closer the spacing of the lamellae. On the other hand, in steels which have been quenched and subsequently tempered,[3] the carbide particles are present as minute spheroids dispersed in the ferrite, and this typical structure is variously known as tempered martensite, sorbite, spheroidized carbides, or secondary troostite. Figs. 2*A*, 2*B*, and 2*C*, showing three stages of agglomeration of the iron-carbide particles, illustrate the typical appearance of steels which have been quenched and tempered. The higher the tempering temperature and the longer the time at this temperature, the coarser are the carbide particles, with corresponding difference in strength and ductility of the metal. For reasons discussed later, tempering is

Prepared for the A.S.T.M.-A.S.M.E. Joint Committee on the Effect of Temperature on the Properties of Metals by the Subcommittee on Grain Size (Project 20). The membership of this subcommittee consists of R. H. Aborn, A. A. Bates, H. W. Gillett, R. F. Miller, and J. R. Vilella.

[1] Normalizing means heating iron-base alloys to approximately 100 F above the transformation temperature range, followed by cooling to below that range in still air at ordinary temperature.

[2] Annealing as used here means heating above the transformation temperature range, holding at temperature for a period of time, followed by slow cooling to room temperature.

[3] Tempering is the reheating of hardened steel (martensite) to some temperature below the transformation range, for an appropriate time, followed by any desired cooling rate.

FIG. 1 THESE ARE PEARLITE STRUCTURES IN 0.85 C STEEL; THE MAIN DIFFERENCE BETWEEN THEM IS THE SPACING OF THE LAMELLAE; THE WHITE GROUND MASS IS FERRITE AND THE GRAY (*A*) OR BLACK STRIATIONS (*B* AND *C*) ARE IRON CARBIDE, ×2500

Figure	Cooling rate	Hardness	
		Rockwell C	Brinell
A	Very slow	5	163
B	Slow	15	207
C	Moderately fast	38	363

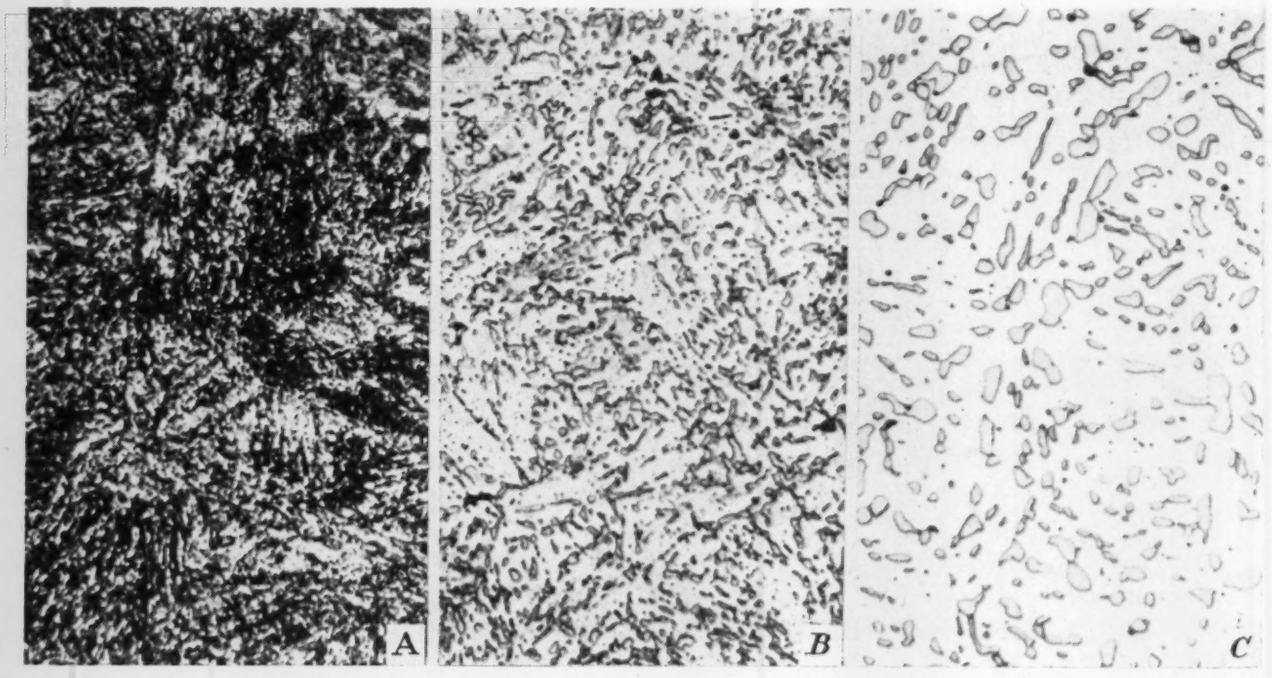

FIG. 2 THESE STRUCTURES ARE TEMPERED MARTENSITE OR SPHEROIDIZED CARBIDES, ×2000. THEY DIFFER PRIMARILY IN THE COARSENESS OF THE CARBIDE PARTICLES. THE WHITE BACKGROUND IS FERRITE

(They were all quenched in water and tempered as follows: *A*, tempered 0.85 C steel, 1 hr at 1020 F (550 C); *B*, tempered 0.89 C steel, 5 min at 1200 F (650 C); *C*, tempered 0.95 C steel, 24 hr at 1200 F (650 C).)

always carried out at temperatures below about 1330 F (720 C), the lower limit of the transformation range.

The important fact to remember is that at ordinary temperatures the ferrite ground mass and the iron-carbide particles exist as separate phases generally identifiable under the microscope. The separate existence of these two characteristic constituents of steel at ordinary temperatures is the result of the inability of ferrite to hold more than a mere trace of iron carbide in true solution. However, in steels which have been quenched to attain maximum hardness (but not tempered), the carbide particles are not visible at any available magnification; the reason for this is that either the carbide particles are too small for microscopic resolution or the iron carbide is actually in unstable (supersaturated) solution in the iron matrix. The structure of a steel thus quenched is acicular and is known as martensite; its appearance under the microscope is illustrated in Fig. 3. Martensite is the hardest, strongest, and least ductile form of steel. While the actual state of the carbon in martensite is uncertain and while it appears that at room temperature martensite is capable of remaining unchanged indefinitely, it begins to decompose slowly into ferrite and spheroids of iron carbide when it is heated to as low a temperature as that of boiling water, and this tempering process goes on faster as the temperature increases.

When a piece of steel is heated, irrespective of its condition at room temperature or of its carbon content if more than about 0.04 per cent, it begins to undergo a radical transformation when a temperature of approximately 1335 F (725 C) is reached.

Up to this temperature, no part of the ground mass is able to dissolve more than 0.04 per cent carbon, but just a few degrees higher those parts of the ground mass in which carbide particles are present acquire suddenly the power to dissolve as much as 0.75 per cent carbon. This sudden change is a manifestation of a profound alteration in the nature of the metal, which the metallurgist recognizes as the appearance of a totally different crystalline form of iron called austenite. Austenite is a solid solution of carbon in the high-temperature crystalline form of iron. The temperature at which the change to austenite occurs is called the *transformation* or, less aptly, the *critical* temperature.

The beginning of this transformation on heating occurs always at practically the same temperature in all plain carbon steels, but the temperature at which the metal becomes 100 per cent austenite varies with the carbon content. It is lowest (1330–1340 F) in a steel of about 0.75 per cent carbon—the so-called eutectoid composition—but rises gradually as the carbon is either less or more than 0.75 per cent. It is for this reason that the heat-treating temperature recommended for, let us say, a 0.20 per cent carbon steel is higher than that for a 0.75 per cent carbon steel.

As is to be expected, the reverse of this transformation takes place on cooling; that is, when austenite is cooled below the transformation temperature range it becomes unstable and eventually transforms to a mixture of ferrite and carbide, the latter being precipitated because the new ferrite phase is unable to hold all the carbon in solution. It must be noted, however, that the transformation on cooling occurs at a lower temperature than on heating. In fact, austenite may transform to ferrite and carbide at any temperature from 1330–1340 F down to approximately 1000 F (540 C), depending on the rate at which the austenite is actually cooling. It may even not transform until room temperature is reached if the cooling rate is sufficiently fast, but a transformation at temperatures between about 1000 F and room temperature can scarcely occur when the cooling medium is at or below room temperature. For an exposition of the modern views on the rate of transformation of austenite and its consequences, the reader is referred to the Bibliography (1, 2, 3).[4] The point to remember is that austenite is really stable only at temperatures above about 1330 F; therefore, it is not present in slowly cooled steels. An appreciable amount may remain untransformed in a quenched high-carbon steel but will transform if the steel is either reheated to about 600 F and held at that temperature for a sufficient length of time, or if it is cooled below room temperature. In general, the lower the temperature the less the amount of retained austenite.

Crystals and Grains. Steel, like all solid metals, is a crystalline aggregate, and within each crystal, its atoms are spaced in the same orderly pattern. This orderly arrangement of the atoms is the fundamental difference between crystalline and amorphous solids; in the latter the atoms are distributed more or less haphazardly. In ferrite, the spacing of the atoms is represented by a cubic array in which there is one atom at each corner of the unit cube and one at the center; this "body-centered cubic" array of the iron atoms is known as alpha iron, and a solid solution in which alpha iron is the solvent is called ferrite. During the transformation from ferrite to austenite on heating, a rearrangement of the atoms takes place, and their new spacing is represented by a cubic array in which there is one atom at each corner and one at the center of each face of the unit cube. This arrangement is referred to as "face-centered cubic" or gamma iron. When gamma iron is the solvent, the solid solution is known as austenite.

[4] Numbers in parentheses refer to the Bibliography at the end of the paper.

FIG. 3 MARTENSITE STRUCTURE IN 0.85 C STEEL, ×2500. ROCKWELL C HARDNESS IS 66, BRINELL 745

In spite of the fact that steel is crystalline at all temperatures below its melting point and under all conditions of mechanical and thermal treatment, its structure under the microscope is not made up of well-formed geometrical crystals, such as cubes or octahedra, but rather of irregularly shaped portions of metal, frequently bounded by curved surfaces, which are known as grains. In each of these grains there is a single and continuous orientation of the array of atoms, but the orientation always varies from grain to grain.

Grains of the same composition and atomic arrangement are attacked by chemical substances at different rates, depending on the orientation initially presented to the corroding medium. This fact enables the metallographer to reveal the confines of each grain, even in the purest metals, by suitable metallographic etching.

The original grains form first when the liquid steel freezes in the ingot mold. Since freezing, or solidification by crystallization, begins at many places simultaneously, the growth of any one crystalline grain is soon interrupted by the growth of its neighbors; consequently, none ever attains either a very large size or the symmetrical shapes usually observed in those cases where each crystal can grow uninfluenced by others. These grains, nevertheless, are much larger than those present later when the steel is wrought. While the principal object of the mechanical hot working of steel is to shape it into useful objects, it also serves to break up the original ingot grains into the much finer ones generally found in rolled or forged sections. It is well to note here that hot working is generally carried out while the steel is austenitic, and cold working when it is ferritic.

GRAINS AND THEIR CHARACTERISTICS

For the purpose of this review, the most important facts pertaining to the grains of steel and their growth are the following:

1 There are in steel only two kinds of grains, the size of which is recognized as influencing its properties—austenite grains and, secondarily, ferrite grains.

2 Regardless of the size of the grains at room temperature,

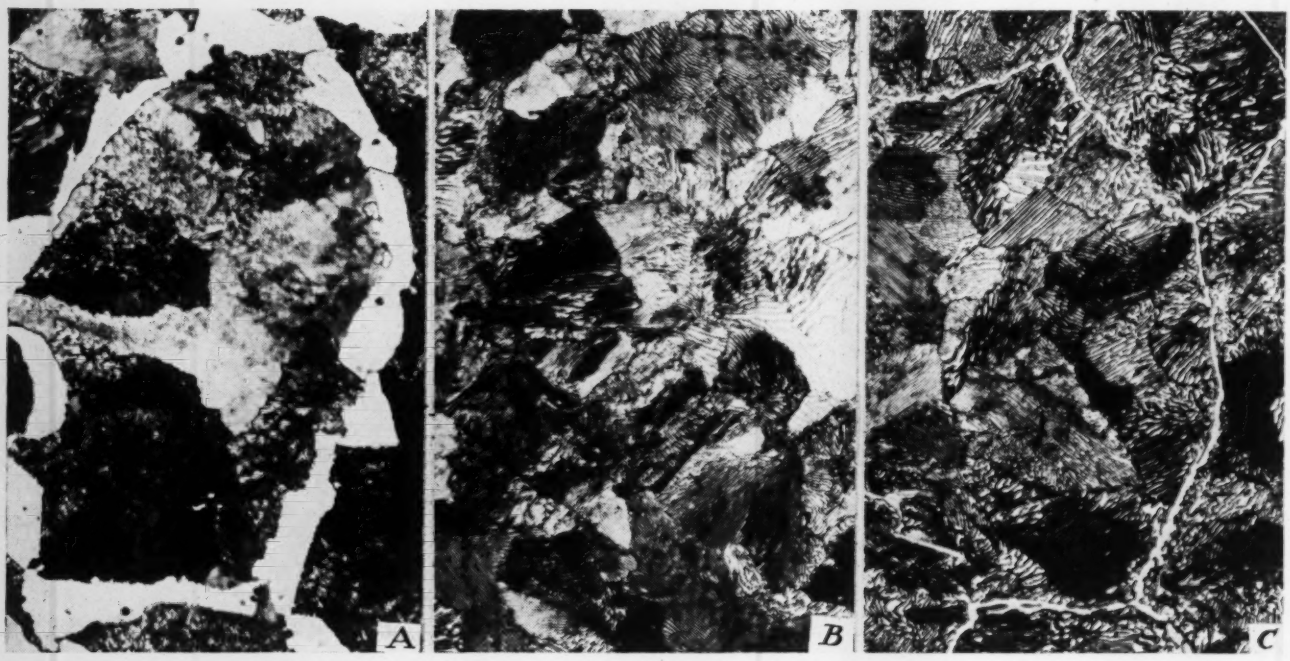

FIG. 4 TYPES OF GRAINS PRESENT IN NORMALIZED OR ANNEALED STEELS OF DIFFERENT CARBON CONTENT, ×500

(In Fig. *A*, 0.40 C steel, the austenite grains are marked out by white ferrite network; the ferrite network itself is made up of ferrite grains; the pearlite areas within the network are made up of pearlite colonies. Fig. *B* is 0.85 C steel—only the pearlite colonies are visible and these do not indicate anything about austenite grain size. Fig. *C* is 1.20 C steel—the austenite grains are marked out by network of iron carbide but within this network the pearlite colonies are visible.)

when steel is heated above its transformation temperature the newly formed austenite grains are initially small.

3 During heating within the stable austenite range, the higher the temperature and the longer the time at that temperature, the larger the austenite grains tend to become.

4 The size attained by the austenite grains at the maximum temperature is not altered by variation in the rate of cooling from that temperature under all ordinary conditions of cooling.

5 Although steels at room temperature are generally ferritic, it is possible, nevertheless, to detect at room temperature the austenite grain pattern which existed at the maximum temperature in the austenite range reached during the last heating period.

6 In the ferritic range (that is, at temperatures below the transformation range of the steel), the tendency of the ferrite grains to grow with increasing temperature is comparatively small, except after they have been deformed by cold work to a so-called critical amount.

7 In general, the faster the cooling rate from the austenitic range, the smaller the ferrite grains; while for the same cooling rate, the larger the austenite grains the larger the ferrite grains.

A more detailed discussion of each of the foregoing statements follows:

1 *The Grain Systems of Steel.* Actually, three types of grain patterns are recognizable in steel, but only two, ferrite and austenite, are generally considered of technical importance. The third type, which is observed only within the pearlite areas, is occasionally referred to as "pearlite colonies." So far no correlation has been found between the size of these colonies and the mechanical properties of steel. The three types are illustrated in Figs. 4*A*, 4*B*, and 4*C*. Note in Fig. 4*A*, illustrating the structure of a 0.40 per cent carbon steel air-cooled from 1600 F, that the white areas of ferrite form a network; this network delineates the antecedent austenite grain pattern. Observe also that the ferrite areas are themselves made up of smaller grains; these are ferrite grains. Now, turning attention to the darker pearlite areas, observe that within the pearlite area surrounded by ferrite there are rather well-defined subdivisions; these are the so-called pearlite colonies.

Fig. 4*B* represents the structure of a normalized 0.85 per cent carbon steel. Since a steel of this composition contains no free ferrite, that is, it is entirely pearlitic, there is nothing with which to outline the austenite grains; therefore, they are not detectable. This apparent "grain" structure is again what we refer to as pearlite colonies.

Fig. 4*C* is the structure of 1.20 per cent carbon steel, furnace-cooled from 1700 F. Two systems of grains are clearly visible; the larger one delineated by a network of iron carbide is the former austenite grain system; the subdivisions of the pearlite areas are, again, the pearlite colonies.

So far metallurgists have paid little attention, if any, to the possible influence of the size of these pearlite colonies upon the properties of the metal. The conditions which appear to affect their size will be referred to later.

2 *The Austenite Grain Size at the Transformation Temperature.* The control of the size of the austenite grains by heat-treatment depends on two facts: (*a*) When ferrite and iron carbide dissolve to form austenite, the size of the austenite grains at birth is small; and (*b*) these small grains tend to grow, and more rapidly the higher the temperature. The growth of the austenite grains with increasing temperature is demonstrated in Figs. 5*A* and 5*B*, representing two specimens of the same 0.35 per cent carbon steel heated 10 min at 1600 F and 2000 F, respectively, and cooled in an appropriate manner to reveal the size of the austenite grains existing at the heating temperature. This is discussed later under "gradient-quench method."

While the size of the austenite grains at birth is small, the size attained just above the transformation range is not always the same; it appears to be influenced by several factors, among

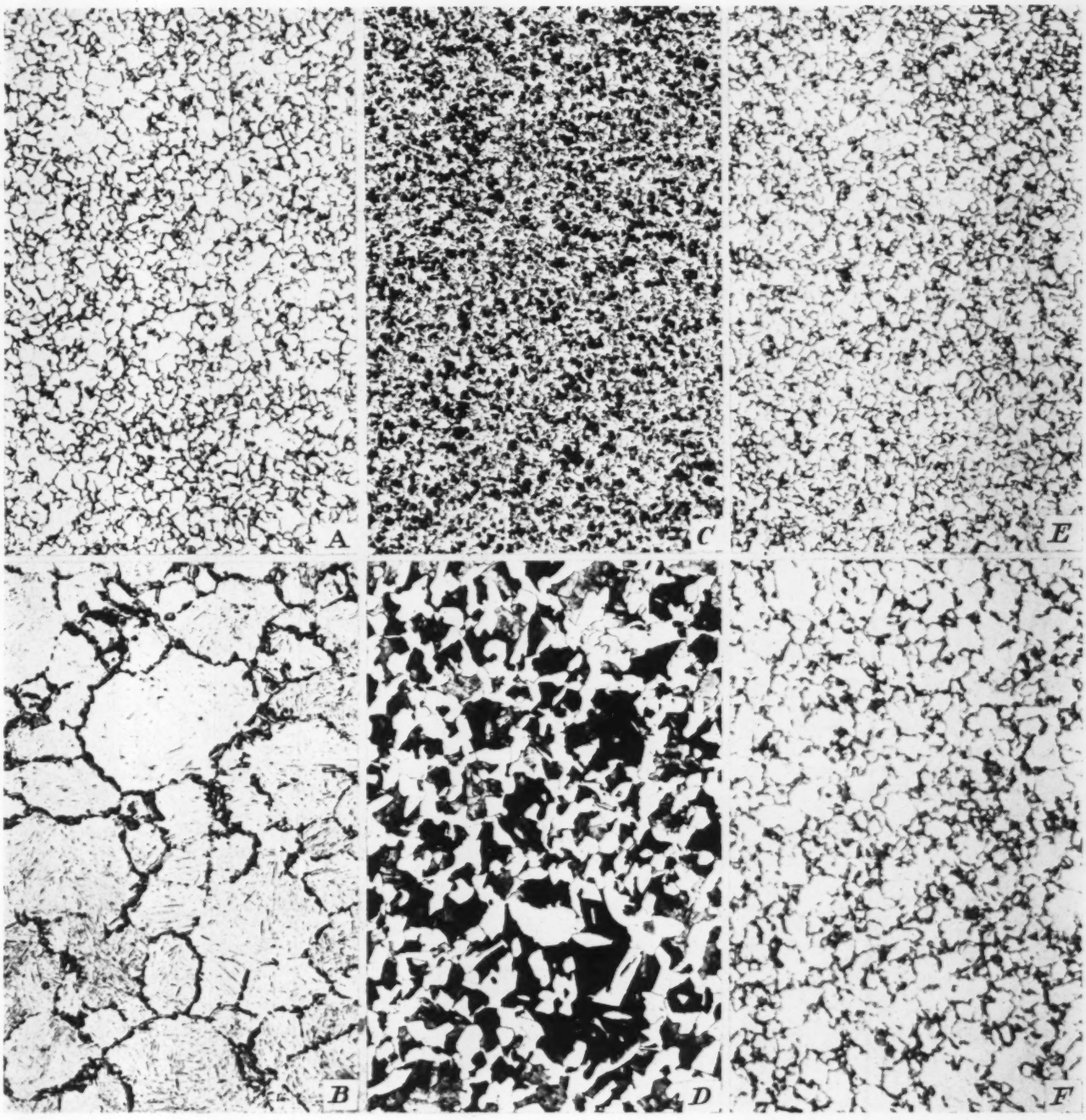

FIG. 5 STRUCTURES OF 0.35 C STEEL

(Figs. *A* and *B* were heated 10 min at 1600 F (870 C) and 2000 F (1095 C), respectively, and cooled in an appropriate manner (gradient-quenched) to reveal the austenite grain size; they illustrate the growth of austenite grains with increasing temperature. Figs. *C* and *D* are, respectively, the structures obtained in two specimens similar to *A* and *B* and similarly heated but cooled slowly with the furnace; the structures consist of pearlite areas (dark) in a ferrite matrix (white). Figs. *E* and *F* show the austenite grain size obtained when specimens *C* and *D*, respectively, were reheated 10 min at 1500 F (815 C) and gradient-quenched; note that coarser austenite grains were obtained from the specimen which originally had a coarser distribution of the pearlite and ferrite areas.)

which is the microstructure of the steel prior to heating. Figs. 5*C* and 5*D* represent two specimens from the same 0.35 per cent carbon steel, heated 10 min at 1600 F and 2000 F, respectively, and cooled slowly with the furnace. Note that the higher temperature produced a coarser distribution of the ferrite and pearlite constituents. These same two specimens were then reheated 10 min at 1500 F (just above the transformation range of this steel) and again cooled to reveal the austenite grain size established at 1500 F. This is shown in Fig. 5*E* and 5*F*. Note that the austenite grain size is somewhat coarser in the specimen which had originally larger ferrite and pearlite areas.

3 *Coarse- and Fine-Grained Steels.* The fact that austenite grains grow with increasing temperature was demonstrated by the previous experiment and shown in Figs. 5*A* and 5*B*, but it must not be inferred that all steels behave alike. The truth is

that in some steels grain growth begins as soon as austenite appears while in others no appreciable growth takes place in a reasonable time until the austenite is heated several hundred degrees higher. The mode of growth of the austenite grains in these two types of steel is illustrated schematically in Fig. 6.

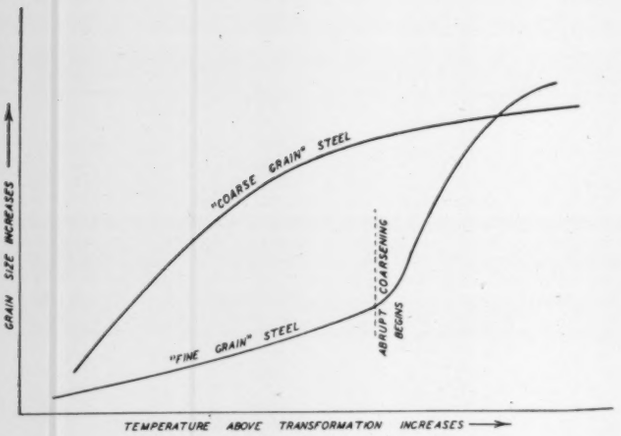

FIG. 6 TREND OF GROWTH OF AUSTENITE GRAINS WITH INCREASING TEMPERATURE IN COARSE- AND FINE-GRAINED STEELS

Those steels which begin to coarsen near the transformation temperature and continue to coarsen with increasing temperature are generally referred to as coarse-grained steels, while those which resist grain growth over a considerable temperature range are known as fine-grained steels. The most important fact, shown by these curves, is that a so-called fine-grained steel is not one immune to grain growth at all temperatures but simply one capable of resisting grain growth over a considerable temperature range, when held at temperature for a reasonable length of time such as is customary in heat-treating practice.

The temperature at which fine-grained steels begin to coarsen rapidly is generally called the coarsening temperature. It differs in different steels and, as will be shown later, is dependent also on the length of time that the steel is held at temperature. The so-called coarse-grained steels coarsen more gradually with increasing temperature, and do not have a well-defined coarsening temperature. In general, in the process of coarsening, all fine-grained steels go through a stage in which more than one grain size is distinctly visible, as illustrated in Fig. 7. This mixed grain size is merely a stage in the normal process of coarsening of any fine-grained steel; whether it is observed or not depends upon the temperature to which the steel was heated and the time at which it was held there. For this reason it is preferable to avoid the use of the term "duplexing" to denote a steel in which mixed grain sizes have been observed; moreover, the term "duplexed" is confusing for it has long been used to designate steels made by a combination of the Bessemer and either the open-hearth or electric processes.

TABLE 1 EFFECT ON GRAIN SIZE OF TIME AT TEMPERATURE

Temperature, F	Time at temperature, min	Austenite grain-size number[a]
1425	20	7
	45	7
	180	90% 7; 10% 3
1625	20	7
	60	75% 7; 25% 4
	180	75% 7; 25% 3
	300	25% 7; 75% 2
1625	20	7
	45	70% 7; 30% 4
	180	5% 7; 95% 3

[a] In this table a small number indicates a coarse austenite grain size, that is, No. 2 grain size is coarser than a No. 7 grain size. This is discussed in more detail later in this paper.

In general the austenite grains grow at a diminishing rate as the time at temperature is prolonged; consequently growth practically ceases, or at least becomes very slow, after a certain size is attained. Data covering a long period of time are not available but those given in Table 1 indicate the trend.

The effect of time at temperature on the size of the austenite grains is also shown in Figs. 8*A*, 8*B*, and 8*C*. The rate of growth of the austenite grains is slowest near the transformation range, but increases gradually and continuously with temperature. In the so-called fine-grained steels, however, there is for each steel a fairly definite minimum temperature above which the grains grow quite fast when the steel is held at that temperature.

4 *Effect of Cooling Rate on the Austenite Grain Size.* Whatever size the austenite grains attain at the maximum temperature, that size remains unchanged as the steel cools to room temperature, provided, of course, the cooling rate is not so exceedingly slow that the metal stays near the maximum temperatures for a long time, in which case some growth may occur. In practice, it is safe to consider the austenite grain size observed in the steel as that attained at the maximum temperature to which it was last heated; this assumption is made in all determinations of austenite grain size.

5 *Methods of Ascertaining the Austenite Grain Size.* In the majority of cases when the metallurgist speaks of grain size, unless ferrite is specified, he is referring to the size of the prior austenite grains, for these are the grains influencing such properties as hardenability, toughness, and, to some extent, machinability. Since it is not convenient to ascertain their size by examination at elevated temperatures, the metallurgist has devised methods of marking out the grains at high temperature for subsequent estimation of their size at room temperature. The unfortunate part of this is that one of the methods

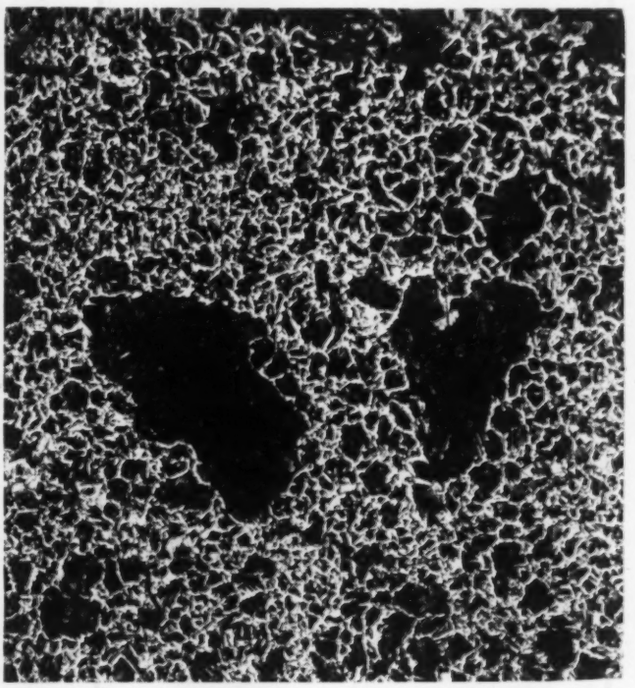

FIG. 7 TYPICAL APPEARANCE OF DUPLEXED GRAIN SIZE (MIXED GRAIN SIZES) IN 0.38 C STEEL, ×100

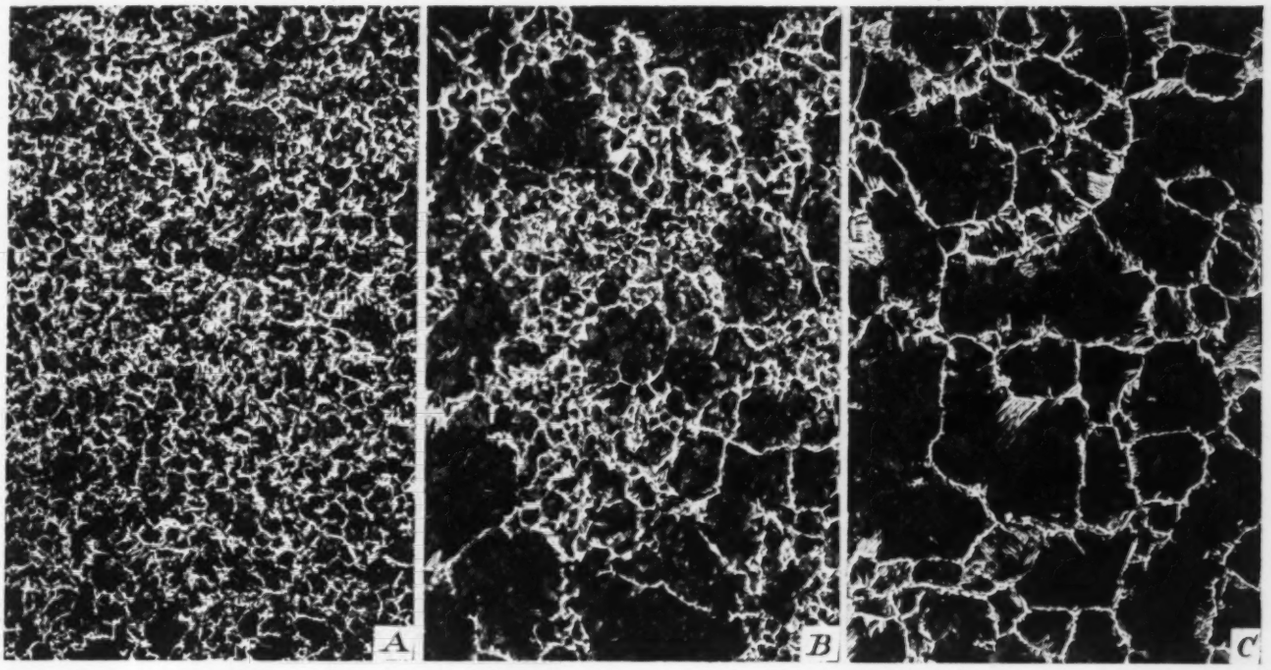

FIG. 8 GROWTH OF AUSTENITE GRAINS WITH TIME AT TEMPERATURE IN 0.38 C STEEL
(Heating temperature = 1625 F (885 C); for *A*—10 min; *B*—30 min; *C*—4 hr.)

in common use, the McQuaid-Ehn carburizing test, differs to such an extent from all the others in principle and technique that it does not always, or necessarily, yield the same result and requires special interpretation. There is no doubt that much of the confusion existing today originates in this fact. Let us therefore examine the methods in some detail and see why the metallurgist, trying to be precise, finds difficulty in avoiding such expressions as McQuaid-Ehn grain size, true austenite grain size, and actual grain size.

The methods commonly used can be classified as (*a*) those which change the chemical composition of the metal in the process of marking out the boundaries of the austenite grains, and (*b*) those based on the fact that under appropriate conditions of cooling, the austenite grains on transforming leave behind "footprints" which disclose their size

The McQuaid-Ehn carburizing method: This consists of pack-carburizing the steel at 1700 F (925 C) for eight hours, followed by slow cooling (4–5 F per min) to room temperature. The metallurgical principle involved is that when austenite containing more than about 0.8 per cent carbon is cooled slowly, the carbon in excess of that amount separates out at the austenite grain boundaries in the form of a thin network of iron carbide, as seen in Figs 4*C*, 16*A*, and 16*B*. The chief merit of this method is that when applied to steels intended for service in the case-carburized condition, it duplicates closely the commercial conditions and yields valuable information as to depth of case, grain size, presence of soft spots, and the normality and abnormality of the case, of which more will be said later; on the other hand, when the method is applied to steels other than the carburizing grades, it requires cautious interpretation for the following reasons: (*a*) Since the composition of the steel is altered by the introduction of carbon and oxygen, the grain size observed is not necessarily that of the original metal; (*b*) since the method calls for eight hours at 1700 F in the carburizing box, the resulting grain size it discloses is not necessarily that which the steel would have when heat-treated for service at lower temperature and for a shorter time; (*c*) since the carbon content of the case differs from that of the core, two entirely different austenite grain sizes are frequently found in one specimen. In short, the only unequivocal information obtainable from this test is whether the grains coarsen or not under the special conditions of the test, i.e., eight hours at 1700 F, with change in composition. In many instances this information is considered sufficient to classify a heat of steel as coarse- or fine-grained, but frequently it is of greater consequence to know the precise temperature at which a steel begins to coarsen in a desired time interval, or the grain size attained as a result of a given heat-treatment. Since the carburizing test cannot supply it, the metallurgist resorts to other methods.

The normalizing method: The normalizing method is one of the simplest and most widely used noncarburizing procedures. It consists of heating a specimen of suitable dimensions to the desired temperature for the desired length of time and cooling it in air. Its main limitation is that it is applicable primarily to steels containing between 0.30 and 0.55 per cent carbon, but in this carbon range it yields excellent definition of the austenite grains, as in Fig. 4*A*. It is based on the fact that in a steel containing less than 0.75 per cent carbon there is an excess of ferrite over the amount required to make pearlite which, when a suitable specimen is cooled at a moderately fast rate, separates out at the austenite grain boundaries forming a network. The method, therefore, uses ferrite as the medium to delineate the austenite grain pattern. It is not applicable to all steels because, when the carbon is more than 0.55 per cent the amount of free ferrite available may not suffice to form a complete network, and when the carbon is less than 0.30 per cent the ferrite is likely to separate out in large patches which do not clearly mark out the grains. But since the method can be carried out under any desired conditions of temperature and time, and since it does not alter the composition of the steel, it is not open to equivocal interpretations; it simply discloses the austenite grain size existing at the instant when cooling started. It is also applicable to high-carbon (hypereutectoid) steels in which case the grains are outlined by an iron-carbide network.

The gradient-quench method: Inasmuch as many steels of

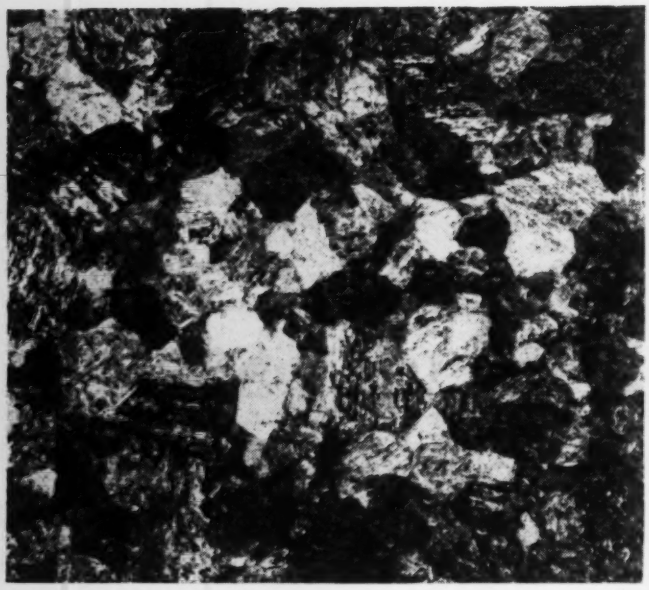

FIG. 9 AUSTENITE GRAIN PATTERN AS REVEALED IN TEMPERED MARTENSITE BY SPECIAL ETCHING REAGENT, 0.40 C STEEL, ×100

great commercial importance are outside the range of carbon content covered by the normalizing test other methods had to be found to ascertain their austenite grain size. The "gradient-quench" method fills this need. It is essentially a means of obtaining automatically the cooling rate which yields the best definition of the austenite grain pattern. It is carried out as follows: A specimen of adequate dimensions (generally $^1/_4 \times ^1/_2 \times 2$ in.) is heated under the desired conditions of temperature and time and cooled by immersing in water about one fourth or one third of its length, allowing the remainder of the piece to cool in air. In this manner a gradient of cooling rates is obtained along the length of the specimen. If a 0.20 per cent carbon steel is thus treated and examined microscopically in longitudinal section, the following sequence of structures is found: (*a*) In the portion cooling under water, martensite; (*b*) in some portion of the metal cooling in the vicinity of the surface of the water, martensite and a network of nodules of extremely finely laminated pearlite which outlines the austenite grains, as illustrated in Figs. 5*A*, 5*B*, 5*C*, and 5*D*; and (*c*) in some region near the top of the specimen, pearlite and a network of ferrite marking out the austenite grain pattern.[5]

If the method is applied to steels containing more than 0.55 per cent carbon, the ferrite network will be missing but a network of dark-etching fine pearlite will be visible; in very high-carbon steels (more than 1 per cent carbon) a network of iron carbide is present. Thus in all cases the method develops one or more areas where the austenite grain boundaries are clearly marked out.

The martensite etching method: It happens sometimes, though rarely, that neither the normalizing, the gradient-quench, nor the carburizing methods yields a satisfactory definition of the austenite grains. In that event the metallurgist may resort to an etching reagent possessing the ability to show

[5] The gradient-quench method was used to obtain the following illustrations in this paper: Figs. 5*A*, 5*B*, 5*E*, and 5*F* in which the austenite grain size is outlined by a network of fine pearlite. The ground mass is martensite. Fig. 7, Figs. 8*A*, 8*B*, and 8*C*, Fig. 12*A*, and Figs. 13*A* and 13*C*; in these the austenite grains are outlined by a network of ferrite. The ground mass is darkly etched pearlite in all except Fig. 13*C*, where it is darkly etched martensite.

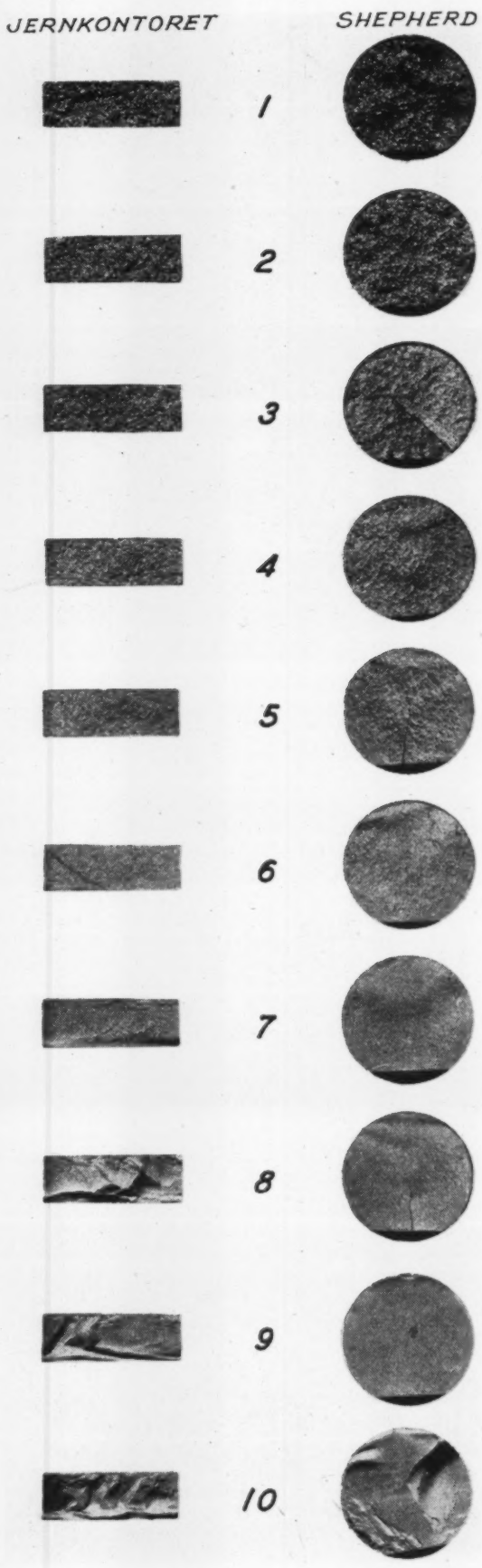

FIG. 10 TWO SETS OF STANDARD FRACTURES FREQUENTLY USED

the austenite grain pattern in steels which have been quenched and tempered slightly (15–30 min at 450–600 F is usually sufficient). This reagent is prepared by dissolving in 100 cc of ethyl alcohol 1 gram of picric acid and 5 cc of concentrated hydrochloric acid. Its action is based on the fact that when austenite transforms to martensite as the result of a drastic quench, the relative orientation of the austenite grains at the heating temperature is not lost completely during the transformation and therefore can be shown by an etching reagent of sufficient sensitivity to differentiate between differently oriented grains. The method is applicable to plain carbon and alloy steels over a wide range of compositions. It can also be used to determine the grain size in the martensitic section of a gradient-quench specimen.

Fig. 9 is a typical photomicrograph of the austenite pattern as revealed by this method. This pattern, which does reveal the prior austenite grain size and is significant in respect to the properties of the steel, may to one not versed in metallography look somewhat like the pearlitic structure in Fig. 4*B*, which does not reveal the austenite grain size and is not significant for our present purpose. The composition and thermal history of the specimen must be known before one can tell whether what is seen under the microscope as an "apparent grain" is or is not a true "footprint" of the prior austenite grains. It sometimes happens that the composition and commercial treatment of a steel are such that the significant prior austenite grain size can be immediately deduced from its microstructure, but this only occurs in rare cases. In the far more common cases where nothing can be told about the austenite grain size without special test, one of the methods described herein must be resorted to if the information is to be secured.

The fracture method: In the fracture method (4, 5), probably the oldest but still a dependable one, a notched specimen of adequate dimensions is quenched drastically from any desired temperature in the austenite range, broken at the notch, and the coarseness of its fracture rated by comparison with a standard set of fractures. There is, however, one all-important precaution to observe: Only the fully hardened, or martensitic, part of the test bar must be considered. In specimens which do not harden to the center, and many do not, there is a pearlitic core whose fracture is not indicative of the austenite grain size, and must be disregarded. The method is best adapted to medium- and high-carbon steels. Fig. 10 represents the two sets of standard fractures most commonly used. It is of interest to note that the two sets are practically identical and graded in steps which, by a happy coincidence, match well the corresponding steps in the standard A.S.T.M. grain-size charts.

Heat-etching method: One limitation common to all the noncarburizing methods available today is their inability to reveal satisfactorily the austenite grain size of steels containing less than 0.10 per cent carbon. This gap is now closed for a technique has been evolved (6) which is applicable to plain carbon and alloy steels of all carbon contents, from a trace to hypereutectoid[6] compositions. The heat-etching method is based on the fact that when a polished steel surface is heated in an atmosphere which is not oxidizing, deoxidizing, carburizing, or decarburizing, the grain boundaries present at the temperature of the test are delineated, presumably by preferential vaporization of the metal at the grain boundaries, without perceptibly altering the chemical composition of the steel. Dry purified hydrogen or nitrogen is a satisfactory atmosphere for the purpose. After the polished specimen is heated to any desired temperature in the austenite range for a desired length of time, it is quenched, preferably in mercury, to prevent oxidation and staining of the polished and etched surface. Fig. 11*A* illustrates the austenite grain pattern of a 0.07 per cent carbon steel heated 10 min at 1900 F, and Fig. 11*B* that of a 0.66 per cent carbon steel after two hours at 2000 F, as revealed by the heat-etching method.

Other methods: In addition to those described, several other methods (7) based on oxidation or decarburization of the austenite grain boundaries are also used. While they also alter the composition of the metal, although to a much less significant extent than the McQuaid-Ehn carburizing method, they are not restricted by temperature and time specifica-

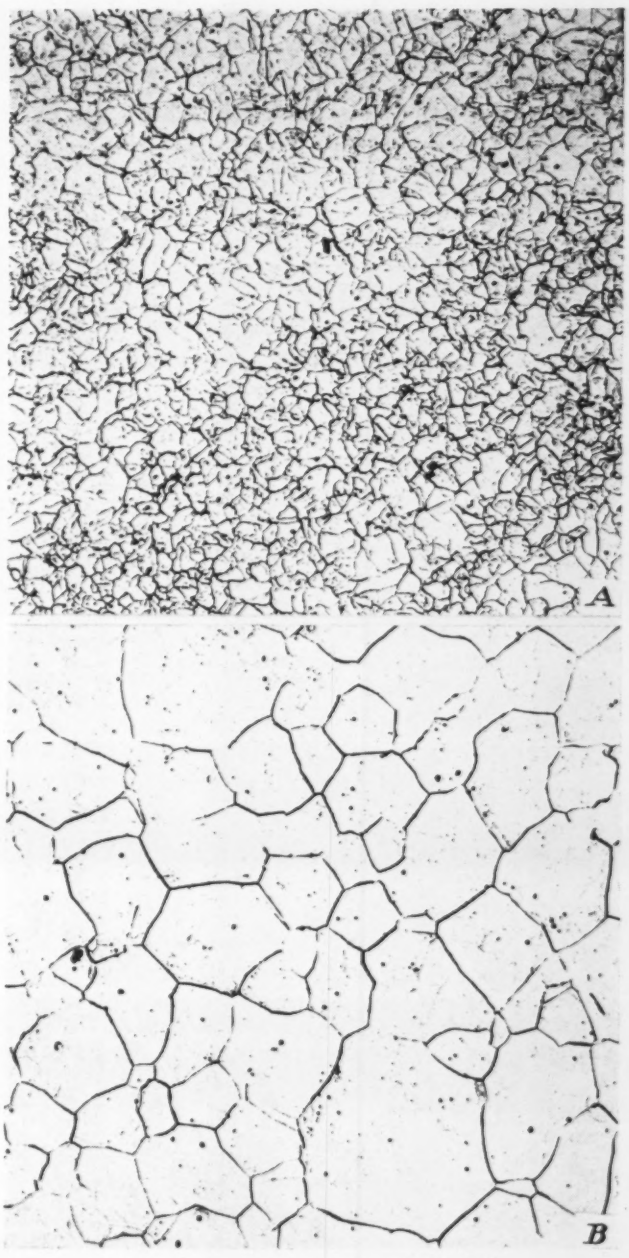

FIG. 11 AUSTENITE GRAIN SIZE AS REVEALED BY THE HEAT-ETCHING METHOD, ×100

(Fig. *A* is 0.07 C steel heated 10 min at 1900 F (1036 C) and quenched in mercury. Fig. *B* is 0.66 C steel heated 2 hr at 2000 F (1093 C) and quenched in mercury.)

[6] The terms hypereutectoid, eutectoid, and hypoeutectoid are used to denote, respectively, carbon steels containing more than 0.75 carbon, just 0.75 per cent carbon, and less than 0.75 per cent carbon. The eutectoid composition is affected by the presence of alloying elements.

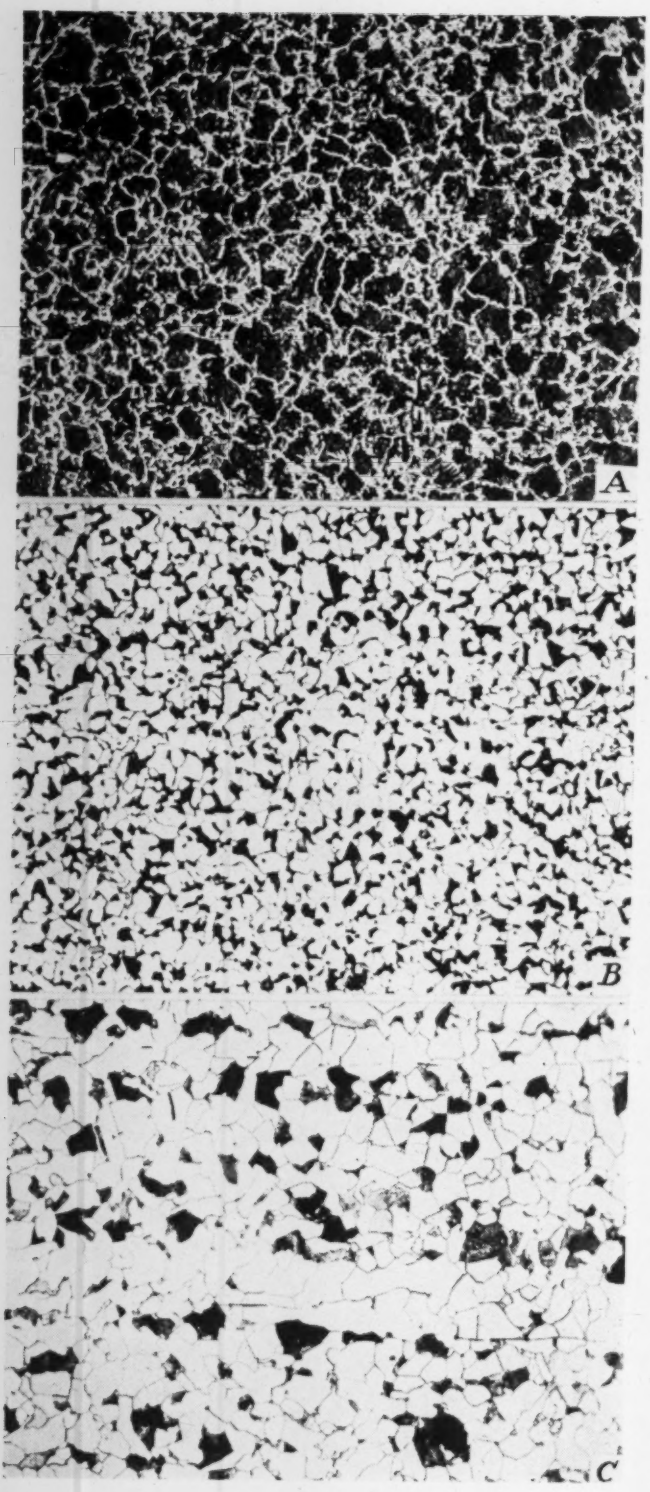

FIG. 12 EFFECT OF COOLING RATE ON FERRITE GRAIN SIZE; 0.20 C STEEL, ×100

(Fig. *A* shows the austenite grain size established in 10 min at 1650 F (900 C); specimen was gradient quenched. Fig. *B* is a specimen of the same steel as *A*, identically heat-treated, but cooled in air; note small ferrite grains. Fig. *C* is a specimen identical to *B*, but cooled slowly with the furnace; note that the ferrite grain size is larger than that of *B*.)

tions. The only reason why they are not described more fully here is because they do not illustrate any point essential to the purpose of this article.

6 *The Ferrite Grains.* Up to this point the discussion has dealt with the size of the austenite grains which existed at the maximum temperature of the heat-treatment. Now let us briefly consider what is known about the ferrite grains and the effect of their size on the properties of steel.

When free ferrite occurs in medium-carbon steel its mere presence and its distribution are generally of greater significance than its grain size; in very low-carbon steel the ferrite grain size is of considerable importance. Because it is difficult in steels containing more than about 0.05 per cent carbon to alter the ferrite grain size by heat-treatment without at the same time altering the size, shape, and distribution of the carbide particles, it has been very difficult to isolate the effect of ferrite grain size on the properties of steel. However, it is known in a general way that, other factors being equal, small ferrite grains contribute hardness, toughness, and strength at ordinary temperature. The size of the ferrite grains also seems to be a factor influencing such properties as deep-drawing quality, resistance to impact at low temperature, creep strength at high temperature within the ferritic range, the electrical properties of special steels such as the low-carbon high-silicon grade, and the yield point of very low-carbon materials (8).

Concerning the growth of ferrite grains at temperatures below the transformation range, it is known to be slow, except in low-carbon steels which have received a so-called "critical" amount of cold deformation. The exception, however, is of considerable interest. In a case recorded by Sauveur (9), specimens of 0.05 per cent carbon steel which were deformed in tension by loads of 38,000, 40,000, 42,000, and 44,000 lb per sq in. and then heated seven hours at 1200 F (650 C) developed different ferrite grain sizes. No appreciable grain growth occurred in the specimen loaded to 38,000 lb per sq in. and only a slight one in those loaded to 42,000 and 44,000 lb per sq in., but in that loaded to 40,000 lb per sq in. an exaggerated grain growth took place. From this and other experiments it was concluded that there is a critical strain which produces abnormally large ferrite grains. Subsequent investigations showed that, within limits, for each degree of cold deformation there is a temperature at which rapid ferrite grain growth occurs. It has also been reported (10) that exaggerated ferrite grain growth occurs when low-carbon steel is heated to 1375–1450 F, provided the metal has been air-cooled previously from 1850 F or higher.

7 *Relation Between the Austenite and Ferrite Grain.* It has been observed that for the same cooling rate, the larger the size of the parent austenite grains, the larger the ferrite grains tend to be. This trend is not difficult to demonstrate when specimens of different austenite grain sizes are cooled at the same slow rate, as shown in Figs. 13*A*, 13*B*, 13*C*, and 13*D*. However, when specimens of low-carbon steel made up of large austenite grains are cooled at a moderately fast rate, as, for example, small specimens air-cooled, the ferrite separates out at the crystallographic planes of the austenite crystals in the form of elongated or acicular areas, which may consist of one or more ferrite grains, alternating with areas of pearlite of the same general shape to form a pattern known as the Widmanstätten structure. In this type of structure it is not always possible to determine accurately the ferrite grain size, but it is unquestionably much finer than the ferrite grain size produced by the slow cooling of austenite grains of the same size. This is clearly shown in Figs. 14*A* and 14*B*, obtained from identical specimens of the same large austenite grain size cooled respectively with the furnace and in the air.

Small austenite grains, on the other hand, can be cooled slowly, or even comparatively fast, without forming the Widmanstätten structure, such as shown in Fig. 12. It is possible therefore, by cooling at a moderately fast rate, to obtain ferrite areas of practically the same size, both from coarse austenite

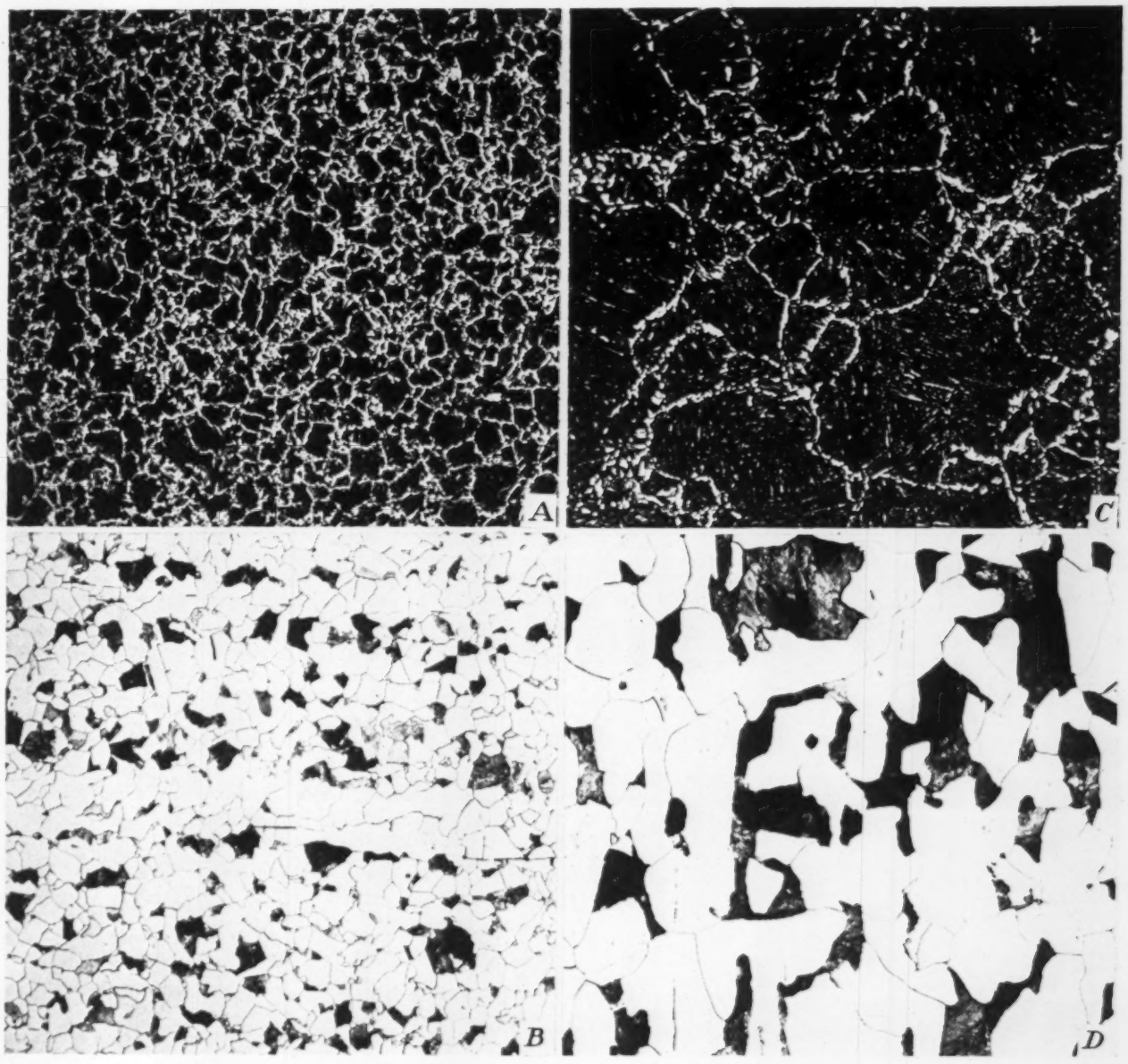

FIG. 13 EFFECT OF AUSTENITE GRAIN SIZE ON FERRITE GRAIN SIZE; 0.20 C STEEL, ×100

(Figs. *A* and *C* show austenite grain size established by heating *A* for 10 min at 1650 F (900 C) and *C* for 10 min at 2000 F (1095 C). Figs. *B* and *D* show ferrite grain size obtained by cooling at approximately the same rate (slowly with the furnace) two specimens treated identically to *A* and *C*. Observe that for the same cooling rate through the transformation range, the larger austenite grains transformed to larger ferrite grains.)

grains which transform to the Widmanstätten structure and from finer austenite grains which transform to more nearly equiaxed ferrite grains and pearlite areas. It is well to add at this point that whatever differences in physical properties are observed between the Widmanstätten and the more nearly equiaxed structures cannot be ascribed to difference in ferrite grain size; it is highly probable that the significant factor in determining the properties of the steel is the shape and distribution of the pearlite areas, that is, the structure of the steel.

The influence of austenite grain size and rate of cooling through the transformation range on the size of the ferrite grains can be summarized as follows:

(*a*) It appears that the ferrite grain size produced as the steel cools through the transformation range rarely, if ever, exceeds the grain size of the parent austenite.[7]

(*b*) The slower the cooling rate through the transformation range, the more closely does the ferrite grain size approach the size of the parent austenite grains.

(*c*) The tendency to form the Widmanstätten pattern, in which the ferrite grain size is probably small, appears to increase first with the size of the parent austenite grains for a given cooling rate through the transformation range, and second with the speed of cooling through the transformation range for a given austenite grain size.

These trends are shown schematically in Fig. 15.

"PEARLITE GRAINS" AND THEIR RELATION TO THE AUSTENITE AND FERRITE GRAINS

Even though occasional references to "pearlite grains" appear in the literature, the concept of a pearlite grain is difficult to reconcile with the definition of the word grain which postulates a crystalline unit of a single phase within which its atoms are arranged in a single orientation. Because pearlite is a lamellar aggregate of two phases, it seems preferable to refer

[7] A possible exception to this rule is highly purified iron, in which large ferrite grains are said to form from small austenite grains.

FIG. 14 TWO SPECIMENS OF THE SAME 0.20 C STEEL, HELD 10 MIN AT 2000 F TO PRODUCE COARSE AUSTENITE GRAINS AND COOLED (Steel *A* was cooled slowly with the furnace and *B* in the air, ×750. Note the radically different distribution of the ferrite and pearlite areas; *B* is the ferrite-pearlite distribution known as Widmanstätten structure.)

to the pearlitic portions of the structure in such terms as pearlite "areas," "regions," or "patches." These pearlite regions must not be confused with the pearlite *colonies* previously mentioned; by a pearlite colony we mean any portion of a pearlite area which appears to be made up of a group of similarly oriented lamellae. The difference between what we are here calling pearlite areas and the colonies comprised in those areas is illustrated in Fig. 17.

The size of the pearlite regions depends largely on the carbon content of the steel and on the rate of cooling through the transformation range. In steels containing between approximately 0.10 and 0.30 per cent carbon, the pearlite areas, as seen microscopically, and ferrite grains are of nearly the same size, as can be seen in Figs. 12*B*, 12*C*, 13*B*, 13*D*, and 14. It will be observed in these photomicrographs that the pearlite areas and ferrite grains maintain their relative size even when their absolute size is changed by varying the cooling rate.

In steel containing between approximately 0.35 and 0.55 per cent carbon, the size of the pearlite areas increases with the rapidity of cooling through the transformation range and with the size of the parent austenite grains. This is the same as saying that there is less ferrite in a given steel specimen when it is cooled rapidly than when cooled slowly, and for a given cooling rate when the parent austenite grains are coarse than when they are fine.

While the factors influencing the size of the pearlite colonies have not been sufficiently investigated to warrant a categorical statement, there are reasons to believe that their size depends both on the cooling rate through the transformation range and on the size of the parent austenite grains, that is, slow cooling and large austenite grains promote the formation of large pearlite colonies.

Inherent Grain Size. This term "inherent grain size" has been used to denote the austenite grain size developed by the McQuaid-Ehn carburizing method as if it were a definite characteristic of the steel, but what has been said up to this point should suffice to show that there is no such thing as an inherent grain size. A steel may be said to possess as an inherent attribute a greater or a lesser tendency to resist coarsening when held at a given temperature for a given period of time, but certainly there is no size of the austenite grains which can be considered a fixed characteristic of a heat of steel. Even its coarsening temperature is variable and it has been found to be influenced

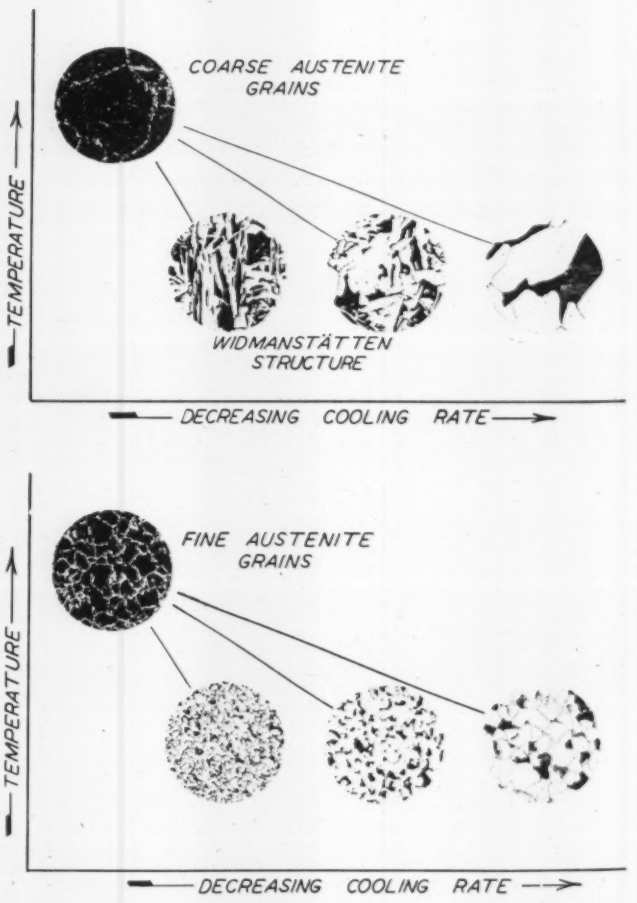

FIG. 15 SCHEMATIC REPRESENTATION OF THE INFLUENCE OF RATE OF COOLING THROUGH THE TRANSFORMATION RANGE AND SIZE OF THE PARENT AUSTENITE GRAINS ON THE SIZE OF THE FERRITE GRAINS AND ON THE FORMATION OF WIDMANSTÄTTEN STRUCTURE

by factors such as time at temperature, rate of heating, finishing temperature, degree of hot and cold reduction, prior structure.

Actual or Existing Grains. A complaint often voiced by men not versed in steel metallography is that the metallurgist is too much concerned with the nonexistent austenite grains and not with the actual or existing grains. Since this complaint is in itself an expression of the confusion existing in matters pertaining to the grain size of steel, it may be of some value to consider some of the possible interpretations which may be given to these phrases.

When a specimen of steel is polished, etched, and examined microscopically, the observer is confronted with a structure in which granular subdivisions, i.e., grains, may or may not be visible. If grains are visible these are, obviously, the actual or existing grains; if the material is largely ferrite, the grain size is that of the ferrite. The structure may, however, be made up of pearlite colonies or "footprints" of the austenitic grains which existed at the maximum temperature above the transformation range to which the steel was last heated. (Since it would be exceedingly cumbersome to have to resort always to long phrases such as "footprints or traces of the parent austenite grains," these are sometimes for convenience referred to as austenite or austenitic grains.) The fact to bear in mind is that although the solid-solution austenite no longer exists as such in plain carbon steels at room temperature, the grain pattern established while the steel was austenitic is very often the actual or existing grain structure observed under the microscope.

It is of the utmost importance to anyone concerned with the grain size of steel to be able to identify the kind of grains present in a structure, for the factors which determine the size of the austenite grains are not the same as those which determine the size of the ferrite grains. Likewise, the properties of steel influenced by the size of the austenite grains are different from those influenced by the ferrite grain size. For these reasons it may be profitable to consider factors determining what type of grain is likely to be present in a given steel specimen.

In plain carbon steels containing from traces to about 0.25 per cent carbon in the as-rolled, as-annealed, or as-normalized conditions, the existing or readily detectable grains are ferrite grains. The reason for this is that in these steels the areas of free ferrite are sufficiently large to disclose the ferrite grain size clearly, but sometimes too large to make a satisfactory network for outlining the austenite grains; this can be observed in Figs. 12*B*, 12*C*, 13*B*, 13*D*, and 14*A*.

In medium-carbon steels (0.35–0.55 per cent) similarly treated, the existing grain pattern that is the most likely to be readily detectable is that of the austenite grains, because in this carbon range the amount of free ferrite which separates at the austenite grain boundaries during the transformation is approximately right to make a satisfactory network. However, with proper preparation of the metallographic specimen it is sometimes possible to bring out, in addition to the austenite grain pattern, a few ferrite grain boundaries within the ferrite areas, and a more or less satisfactory definition of the pearlite colonies, as is shown in Fig. 4*A*.

In steels containing from about 0.75 to about 1 per cent carbon in the as-rolled, as-annealed, or as-normalized conditions, it is extremely difficult, if at all possible, to estimate the former austenite grains, because there is not sufficient separation of either ferrite or iron carbide to mark out the network. What some have called existing grains in these steels can only be pearlite colonies, though these are detectable only in correctly prepared specimens, as in Fig. 4*B*.

In steels containing more than 1 per cent carbon, in the as-rolled, normalized, or annealed conditions, the existing grain pattern is that of the parent austenite grains. In these steels

FIG. 16 THE STRUCTURAL CHARACTERISTICS OF A SO-CALLED NORMAL STEEL IS SHOWN IN *A*; *B* SHOWS THOSE OF A SO-CALLED "ABNORMAL" STEEL, ×1000

there is a sufficient amount of carbon to form a network of free iron carbide around the austenite grain boundaries. In carefully prepared specimens it is also possible to see the pearlite colonies, as, for example, in Fig. 4*C*.

Generally, no grains are detectable in a steel which has been cooled from above its transformation range at a rate sufficiently fast to make it 100 per cent martensitic, unless the specimen is tempered and etched as described previously, in which case the austenite grains are revealed. (Compare Figs. 3 and 9.) However, when a specimen is cooled from above its transformation range at a rate slightly slower than that required to make the steel 100 per cent martensitic, some nodules of finely laminated pearlite are likely to be formed at the austenite grain boundaries, as in Fig. 5. In this case the existing or readily visible grain pattern is again that of the prior austenite.

The expression "actual austenitic grain size" is sometimes used to bring out clearly the fact that a determination of the austenite grain size was made on the steel specimen when subjected to the same time and temperature in the austenitic

range as in the heat-treatment applied in the preparation of the steel for its commercial use, in contradistinction to the time, temperature, and environment specifications of the McQuaid-Ehn carburizing test.

The term "carbide grain size" has occasionally been used, apparently to denote areas comprising particles of carbide; however, it is a misleading term, as the only real carbide grains are the individual particles of carbide.

Summarizing the preceding remarks on the use of such expression as actual, existing, inherent, and carbide as applied to the grain size of steel, it may be said that:

(*a*) Inasmuch as alternative phrases of perfect explicitness, such as austenitic or ferritic grain size have always been available, the use of less precise phraseology has introduced unnecessary ambiguity and at times cast doubt on the ability of the user of the term to identify type of grain to which he alluded.

(*b*) Since the concept of an "inherent grain" size is not supported by the experimental evidence now available, that expression is meaningless and its use is to be avoided.

(*c*) The use of the phrase "McQuaid-Ehn grain size" to denote the austenitic grain size obtained under standardized conditions (carburization at 1700 F for eight hours followed by slow cooling) carries no ambiguity and its continued use does not appear objectionable. It must be understood, however, that it always refers to the austenitic grains developed at one specific temperature and time under the special conditions of the method which alters the composition of the steel.

Normality and Abnormality. This subject has been discussed by other authors (11, 12). In the study of variations in the hardenability of low-carbon steels as case-carburized, made by McQuaid and Ehn, it was observed that steels which hardened uniformly on quenching after carburization could be differentiated from those which developed soft spots by the structural characteristics of the carburized case as observed on specimens which have been cooled slowly instead of quenched. On slowly cooled specimens these differences were noted:

Good hardenability	*Poor hardenability*
Coarse austenite grains	Fine austenite grains
Fine pearlite	Coarse pearlite
Pearlite contiguous to carbide network	Pearlite separated from carbide network by ferrite
Continuous, thin carbide network	Coarser, more discontinuous and irregular network

Some of these differences are clearly illustrated in Figs. 16*A* and 16*B*.

The structure of a steel capable of satisfactory hardening was thus referred to as being normal while that of a steel of poor hardening properties was said to be abnormal. The words might have been well chosen at the time to classify the steels intended for service as carburized, but in the meantime the test has been extended to other grades and the implication of desirable and undesirable properties still lingers when this terminology is used. The fact is that normality and abnormality as used by metallurgists today when referring to steel other than the carburizing grades in no sense imply good or poor quality. Each type possesses properties that make it preferable for certain specific purposes.

TABLE 2 INFLUENCE OF AUSTENITE GRAINS UPON STEEL BEHAVIOR

Property	Austenite grain size — Coarse	Fine
Hardenability	Deeper	Shallower
Tensile strength (steel normalized)	Higher	Lower
Ductility (steel normalized)	Lower	Higher
Impact strength	Lower	Higher
Carburized structure (McQuaid-Ehn test)	Normal	Abnormal
Machinability, rough	Improved	Impaired
Machinability, finish	Impaired	Improved
Transformation temperature	Lower	Higher
Quenching cracks	Frequent	Very rare
Grinding cracks	More susceptible	Less susceptible
Distortion in heat-treating	Greater	Less

Effect of Austenite Grain Size on Properties of Steel. An important effect of austenite grain size on the properties of steel is its effect on hardenability (13). The trend of the influence of size of the austenite grains (assuming constant composition of the steel) upon steel behavior is given in Table 2.

Estimation of Grain Size. The usual procedure for evaluating the austenite grain size of a specimen is as follows: The specimen is treated by one of the methods previously described, given a metallographic polish, etched with a suitable reagent, and the structure thus obtained projected on the ground glass of the microscope at a magnification of 100 diameters. Its grain size is determined by comparison with a standard chart.

Since the measurement is always made upon a plane surface the grain size reported always refers to the area of the cross section of the grains. The grain size is indicated by an index

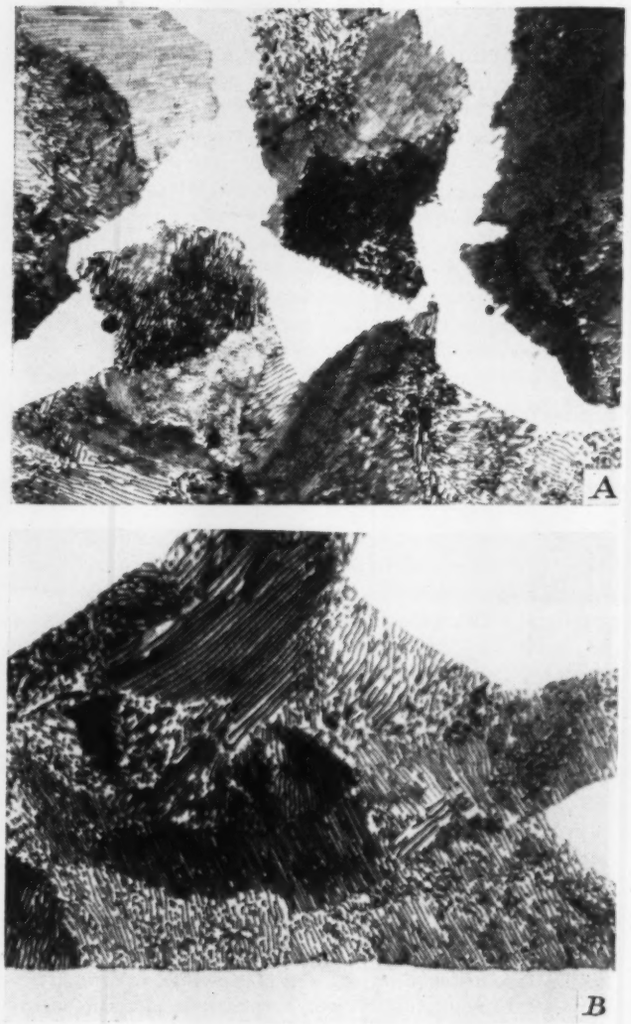

FIG. 17 PEARLITE AREAS AND COLONIES

(Fig. *A* shows the regions of pearlite surrounded by ferrite are the pearlite areas; the variously toned portions comprised within these areas, each made up of similarly oriented lamellae, are the pearlite colonies; normalized 0.45 C steel, ×750. Fig. *B* shows a single pearlite area within which several colonies are clearly discernible; normalized 0.20 C steel, ×1500.)

TABLE 3 GRAIN SIZE CORRESPONDING TO A.S.T.M. INDEX NUMBERS

A.S.T.M. grain-size number	Number of grains per sq in. at ×100		
	Mean	Maximum	Minimum
1	1	1.5	0.7
2	2	3.0	1.5
3	4	6.0	3.0
4	8	12.0	6.0
5	16	24.0	12.0
6	32	48.0	24.0
7	64	96.0	48.0
8	128	192.0	96.0

number which refers to the number of grains existing in one square inch of the image at a magnification of 100 diameters. The correlation of these index numbers with the actual number of grains per square inch of image at 100 magnification is given in Table 3.

The standard chart for carburized specimens (A.S.T.M. E19-33) consists of two series of photomicrographs representing the hyper- and hypoeutectoid portions of the case of case-carburized specimens, graded in eight steps which correspond closely to the calculated number of grains per square inch given in the preceding table. The corresponding chart (A.S.T.M. E19-38T) for all other specimens is a series of grain outlines graded in the same eight steps.

While a magnification of 100 diameters is generally used during the actual estimation at the microscope, a lower magnification is preferable for very coarse grains, or a higher magnification for the extremely fine grains sometimes found in alloy steels. The same chart is used to match the image, but in reporting the grain-size number the following rules must be observed: For each doubling of the 100 times magnification the grain size is reported as two more than that which it matches on the chart; for each halving of magnification, as two less than that matched on the chart. Thus, if a structure at ×400 matches the No. 2 grain size of the chart, its grain size is No. 6. If a match is found at ×50 with the No. 3 grain size of the chart, the grain size is reported as No. 1.

Effect of Alloying Elements on the Austenite Grain Size. In general, those elements added to steel which combine with carbon to form carbides, or with oxygen to form a finely divided dispersion of oxides, tend to enhance resistance to grain growth (14). The generally accepted explanation for this effect is that the carbides or oxides of these elements are capable of remaining both undissolved and unagglomerated over a considerable temperature range, and as long as they remain in this optimum condition they somehow provide an effective obstruction to grain growth. As soon as they dissolve, or coalesce to form larger particles, they cease to be effective inhibitors, and the grains then grow rapidly, often attaining a larger size than that observed at the same temperature in unalloyed steels.

Elements such as nickel or copper, which do not form carbides, do not seem to affect the grain size markedly.

Effect of Austenite Grain Size on the Rate of Transformation of Austenite. One of the most important contributions of austenite grain size to the properties of steel is its effect on the depth to which a given section hardens on quenching (hardenability) (15). Davenport and Bain (16) showed that the rate at which austenite transforms to ferrite and carbide is greatly influenced by the austenite grain size. Since the transformation on cooling generally begins at the austenite grain boundaries, it follows that a steel in which there is more boundary surface (fine austenite grains) will transform at a faster rate than one in which there is less boundary surface (coarse austenite grains). For reasons that are too lengthy to state in this review, a slow transforming steel can be made martensitic by cooling at a rate slower than that required for a steel which transforms more rapidly. In other words, coarse austenite grains require a less drastic cooling rate to form marteniste. This means that, on quenching, a given section of steel will harden to a greater depth when its austenite grains are coarse.

It is realized that this review has not touched upon all the aspects of the grain size of steel, nor discussed exhaustively those touched upon, but it is hoped that it has laid a foundation for more advanced reading by those interested in pursuing this subject. The various aspects of the austenite grain size of steel have recently been reviewed by Ward and Dorn (17) and Bastien (18). The reader is referred to these articles for a more detailed discussion of some points barely touched in this introduction to the subject and for an extended bibliography.

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Some Remarks on MATHEMATICS *From the* ENGINEER'S VIEWPOINT

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THE Handmaiden of the Sciences" is the title of a very instructive book by the prominent mathematician, my friend and colleague, E. T. Bell. I must confess that we engineers do not always have the feeling that mathematics is a handmaiden of *engineering* science. The famous German poet, Johann Wolfgang von Goethe, wrote a poem about the magician's apprentice whose master was able to make spirits serve him. He learned from his master the power of evoking the spirits but forgot the magic word to control and stop them. Sometimes we have the feeling with mathematics that we have learned to start the mechanism of mathematical operations, but after the gears begin to work the machine gets out of hand and we do not know what it is doing or where it is going. In other words we are not able to follow the physical significance of the successive steps, and wonder how to interpret the outcome. This is perhaps one of the reasons why, although every engineer studies quite a lot of mathematics, so few really use it.

Of course, every engineer uses the elementary mathematical operations and understands the basic mathematical ideas. Let us see how the mathematician builds up the system of fundamental conceptions. He starts with the integral number. "God made the integers, everything else is the work of man," said Kronecker, a noted mathematician of the nineteenth century. The conception of negative, rational, and irrational numbers is easily grasped by the engineer. It is evident to him that a number must exist equal to $\sqrt{2}$ since this number measures the side of a square whose area is 2, or that there must be a number π which determines the ratio between the circumference and the diameter of a circle, although these numbers cannot be expressed as quotients of integral numbers. However, he might feel uncomfortable if he were to encounter imaginary numbers. He would say that in the world there are only real quantities which we can measure, such as length, time, weight, and the like. There is no imaginary length or imaginary time or imaginary weight. He has the feeling that the idea of the imaginary number has a touch of unreality. As a matter of fact, at the time that the imaginary number was invented its conception was not free of mysticism. "The imaginary number," says Leibnitz, "is a wonderful recourse of the divine spirit, something of an amphibian between being and nonbeing." Now we do not believe that the imaginary number is suspended between being and nonbeing; we rather believe that it is a useful artifice for abbreviating complicated calculations by use of certain symbols; in other words, it is a kind of mathematical shorthand. The electrical engineer uses complex numbers and especially exponential functions with complex exponents to abbreviate the calculations of periodical phenomena, of the behavior of rotating machinery, and the like. Sometimes we use the complex number for geometrical calculations, such as the addition or multiplication of vectors or for the description of the phenomena of two-dimensional flow. We are often amazed how beautifully the artifice works. As a famous mathematician expressed it, "Mathematics is sometimes more intelligent than the people who use it."

The most widely used tools of engineering mathematics are, of course, differential and integral calculus, including differential equations, at least some of their simpler species. At the time that these tools were invented and developed there was no border line between pure and applied mathematics or between science and engineering. At the rear of Trinity College in Cambridge, England, there is an old, nicely designed, wooden bridge. The consulting engineer for the stress analysis of this bridge was a certain Sir Isaac Newton, Lucasian Professor of Mathematics at the University of Cambridge. We know that the Bernoullis and Leonhard Euler created essential parts of the science which is known in the engineering curriculum as applied mechanics. The theory of buckling and the theory of water turbines were originated by Euler. He also wrote a learned paper on the force necessary to drive piles into the soil. Eighteenth-century mathematics was mainly directed toward the understanding of the phenomena of the physical world and the solution of practical, or in modern terminology, "engineering" problems. This period in the history of mathematics can be called the constructive period; I prefer to call it the "heroic" period because at that time mathematical science could achieve almost miraculous results by relatively simple means.

A separation between pure and applied mathematics began to appear in the nineteenth century and, perhaps, reached its climax in the middle of that century. I would call this age the era of codification. The mathematicians of the heroic era were not discouraged from using methods whose axiomatic foundation was incomplete from a purely logical viewpoint. Their minds were directed toward obtaining practical results. Like the engineer of today, they were not always quite so scrupulous about the legitimacy of the operations used as are modern mathematicians. In the era of codification the critical spirit prevailed; definitions and classifications were examined and reexamined for their logical foundation, freedom from contradiction, and completeness. The pure mathematician became to some extent like the doctor who is more interested in the diseases of the human body and in the disorders of physiological and psychological processes than in the normal functioning of body and mind.

Let us illustrate the difference of viewpoint by the example of the concept of a function. If the engineer speaks of a function, he generally has in mind a continuous function. He will readily include functions that have a number of discontinuous points. In the case of an oscillatory function he will assume that the function reaches its maxima and minima at certain discrete points. Functions that have an infinite number of maxima and minima, or an infinite number of discontinuities in an arbitrarily small interval, will appear to him to be abnormal. However, it is easy to define functions with such properties, and they have considerable interest to the pure mathematician. For example, $\sin(1/x)$ obviously has an infinite number of maxima and minima in the interval between zero and an arbitrarily small number ϵ, say $1/10^6$, because in the interval

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$0 < x < 1/10^6$ the reciprocal value of x varies from 10^6 to ∞ and the sine function has an infinite number of maxima and minima if the argument runs from one million to infinity. Or, let us define a function in the following way: $f(x)$ is equal to $+1$ if x is a rational number, say 1/2, 4/3, 16/5, etc., but it is equal to -1 if x is an irrational number, say $\sqrt{3}$, $\sqrt{5}$, π. Now, between any two numbers a and b, there is an infinite number of rational numbers and an infinite number of irrational numbers. Consequently, the function has to jump an infinite number of times between $+1$ and -1. This is certainly a function which, as an engineer, I would not call a healthy function. I would say at least that it is emotionally unstable.

Certainly the pure mathematician cannot be bound in his conception of a function by practical considerations of immediate usefulness for the description of physical phenomena. However, one can easily understand that the mentalities of the mathematician and the engineer necessarily diverged in the period of criticism and codification. On the one hand the engineer lost his sense of security in the use of the tools of mathematical analysis. For example, he thought for many years that a definite integral was simply an expression for an area; he learned either to calculate it if the boundaries of the area were given by simple functions or to determine its value by an integraph or planimeter. Suddenly he was told that there are various definitions of an integral, some of them quite intricate; there are integrable and nonintegrable functions. Also he based certain methods of approximation primarily on his physical intuition; now he became uncertain about them if he was not able to establish a proof of convergence beyond doubt. On the other hand the mathematician considered the engineer as a scientist of lower rank, who lacked the sense and ability to grasp the sublime scientific truth built up on the unshakable foundation of pure logic. (It is comforting to the engineer that recent developments of mathematical logic shattered the complacent confidence of the mathematician in the very foundation of his own science.) This more or less hostile feeling between the two kinds of mentalities eventually found expression in the engineering literature. Most engineers dared not openly revolt, but some of them had an independent revolutionary spirit and gave vent to their feelings at least through wisecracks. For example, the great British physicist and electrical engineer, Heaviside, says something like this in one of his papers: "This series is divergent according to the mathematicians, hence, I believe I can really do something with it." Another time when his attention was called to the fact that his operational methods, which belong to the most important mathematical tools of electrical engineering, could not be proved exactly, he answered: "Shall I refuse a good dinner because I cannot understand completely the process of digestion?"

Many engineers were handicapped in their use of mathematics by the formalistic development of some branches of analysis. We all use the so-called circular functions, e.g., sine and cosine, not only for trigonometrical calculations, but also for the representation of the laws of harmonic oscillation, which is the simplest periodic motion. In other words, these functions are solutions of a second-order differential equation which is familiar to us as the differential equation of harmonic oscillation. We say that this differential equation defines the class of circular functions; similarly differential equations of more complicated structure define a great variety of functions such as Bessel, Legendre, Hermite, Mathieu, hypergeometric, gamma, theta, zeta functions, and the like. All these special functions have very interesting properties worth being studied, and in some cases these properties, are even quite useful. However, there seems no end of such functions, or of their interesting properties. A mathematician can live on a few functions all his life. Unfortunately, the theory of such functions fills a great portion of some mathematical textbooks and curricula. Many hapless engineers think that in order to use mathematics they have to learn all about such functions. This is as sensible as memorizing Webster's dictionary from a to z to learn the English language. (Of course it is true on the other hand that the mathematical vocabulary of quite a few engineers is comparable only with the 200–300 words of pidgin English.)

I believe that the engineer needs primarily the fundamentals of mathematical analysis and sound methods of approximation, but he has only a restricted use for the great science of special functions. I do not deny that some of the special functions, especially those that owe their origin to physical problems, are very useful for scientific engineers. Their greatest merit perhaps is that they are nicely tabulated and these tables certainly abbreviate the numerical work in many cases. However, even if the solution of a problem can be expressed by known special functions, often an approximation by algebraic or trigonometric series will be more practical for the engineer as it will require less work and cause less worry. Hence, in the mathematical training of a young engineer I would rather emphasize the fundamental theorems of analysis. It is interesting to note that the fundamental mathematical theorems and the engineering methods of approximation are more closely related than one would imagine. Take, for instance, the following example. You have to calculate the critical speed of a shaft of very complicated shape. You might set up the differential equation, but if you show this equation to a mathematician who knows all about differential equations, he will tell you that it is hopeless to try to solve it exactly. Then what would you do? You would assume an arbitrary shape of deflection which looks plausible to you. Then you would calculate the centrifugal forces resulting from the rotation of this deflected shaft. If your guess was 100 per cent correct, the calculated centrifugal forces would keep the shaft exactly in the assumed deflected position. You may find that this is not the case. Then you would recalculate the deflection corresponding to these centrifugal forces acting as load on the shaft, i.e., you would correct in this way the arbitrarily assumed shape. Now because the shape of deflection is changed, also the distribution of the centrifugal forces is changed. Consequently, you would correct the centrifugal forces and again calculate the deflection due to these corrected forces. If this is repeated a few times, you will notice that the corrections become negligibly small. This procedure is essentially identical to the method of iteration or successive approximations of mathematical analysis. As a matter of fact, it is one of its most powerful and widely used methods for the proof of the existence and uniqueness of solutions. The main difference is that the engineer has been led by his mechanical feeling and intuition and feels satisfied if the correction becomes negligible. The mathematician has to prove that by repeating the iteration an arbitrary number of times he can approximate the exact result with an arbitrary accuracy.

The method of iteration is only one example of the methods of modern applied mathematics that have their counterpart in mathematical analysis. These methods of applied mathematics are not all new; many of them are revivals from the classical period of mathematics. However, they have been taught and emphasized only in the last half century. It is difficult to separate in the development of science the impact of the needs of the time and the influence of personalities. I only want to mention two men closely connected with the renaissance of applied mathematics. The first is Lord Rayleigh, prominent representative of the great British school of mathematical physics, and the second is Felix Klein, considered as the founder of the so-called Göttingen school of applied

mathematics and mechanics in Germany. Felix Klein was a pure mathematician in the field of geometry and the theory of functions. He became interested in applying mathematics to engineering after his first trip to the United States; I believe it was during the time of the first world's fair in Chicago. His visit to America convinced him that in view of the great natural resources and the beginning success of mass manufacturing methods of the American industry, nations less blessed by nature have a chance in international competition only if they refine their scientific engineering by the extended use of mathematical methods. He actually found support among industrialists to carry out his ideas and succeeded in establishing in Göttingen a center for applied mathematical research.

Applied mathematics became essential in the development of the theory of elasticity, strength of materials, fluid mechanics, and especially in electrical and aeronautical engineering. It is often said that the latter two branches of engineering require more intricate mathematical methods than other fields of engineering. I do not believe that this is necessarily true although these two branches were early forced to make use of more advanced mathematics. Compare, for example, hydraulics and aeronautics. We know that the flow of a fluid through a pipe is a complicated physical phenomenon if we take into account all properties of turbulent flow; nevertheless, for approximate calculations we can replace the velocity distribution by a uniform mean velocity. However, such an engineering approach will yield little information about the forces and moments acting on an airplane wing and we have to carry out an analysis of the distribution of velocities and pressures in three, or at least in two, dimensions. However, I do not believe that aeronautical engineering has an exceptional position. If we really try to understand the flow in a centrifugal pump it is at least as complicated as the flow problems in aeronautics. The time soon will come, or is already here, when mathematical analysis will be applied in almost all branches of engineering. The question is how closely do we intend to follow the physical phenomena, and how much experimental work has been done to make the application of higher mathematical methods possible. The engineering application of mathematics is not based on purely logical principles alone; its purpose is the correct interpretation of physical phenomena. The engineer has first to observe and then to calculate.

It is a paradoxical fact that mathematics in this country leans more toward abstract and pure mathematics than it does in most of the leading European nations, in spite of the fact that engineering plays a much bigger role in American life than in the life of those countries. I believe one reason is the following: In the second half of the nineteenth century most of the young American mathematicians studied in Europe and especially in Germany. The school that I called the school of codification was flourishing at that time in the German universities. These American students became interested mostly in the abstract problems of mathematics, and only a few of them came in contact with applied mathematics. This was one of the decisive factors in the development of American mathematics. Also, many representatives of the so-called formalistic British school interested in special functions and mathematical artifices were active in this country both in teaching and mathematical research. However, in recent years vigorous effort has been made to alter the situation and applied mathematics has taken its proper place in literature and schools. More and more engineers learn the fundamentals of analysis; more and more workers in mathematics become interested in engineering problems.

Of course there always will be a difference in the viewpoint of the abstract scientist and the practical engineer. A prominent naturalist when asked whether he, as a scientist, would be interested in the question of the immortality of the soul of the June bug, replied: "Certainly if the problem could be solved by scientific methods." This reply perhaps goes too far, however, the scientific mind will never be limited to questions of immediate usefulness to mankind. Nevertheless, it seems to me that we witness a certain revival of the spirit of the heroic age with a better mutual understanding between the mathematician and the engineer. The practical engineer appreciates the advantage of replacing mere empiricism by scientific analysis expressed in mathematical language. At the same time even the most abstract mathematician considers the usefulness of his science at least as a gracious by-product of his brain work.

STEEL AND STONE IN SILHOUETTE

(Photograph taken by Oswald Rothmaler and shown at the Fourth Annual Photographic Exhibit held during the 1939 A.S.M.E. Annual Meeting in Philadelphia.)

Significance of TENSION TEST

Background of a Proposed Symposium to Discuss Relation of Tensile Test of Metals to Design

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AT THE annual meeting of The American Society for Testing Materials which will be held at Atlantic City, in June, 1940, a Symposium will be conducted on the subject "Significance of the Tensile Test in Relation to Design." This Symposium will be devoted to the presentation and discussion of a group of papers dealing with the tensile test of metals, with the twofold object of attempting to clarify the relationships between fundamental characteristics measured in such a test and, in addition, the relating of such characteristics to the design problem.

The value of such a Symposium will depend very largely upon the amount and character of the discussion which these papers develop. Therefore, it is earnestly hoped that all those engineers who are interested in inquiring into the physical significance of the quantities determined from the tensile test and their relationship to design will take part in the discussion so that the basis of our present knowledge on this subject may be considerably broadened.

In order to prepare the way for such discussion, the author, who is chairman of the Symposium Committee, the members of which are Col. G. F. Jenks, Prof. H. F. Moore, N. L. Mochel, and R. E. Peterson, has prepared some observations on the tensile test which are herewith presented.

The Symposium will consider only the tensile test as made at normal temperatures and will not attempt to explore the effects of either high or low temperatures.

FORMS OF TESTS USED

The various forms of tests used by the engineer to assess his materials may be divided into two groups (*a*) fundamental type and (*b*) arbitrary type. The first type provides data which may be used directly for design purposes. The tensile test is one of the most important, if not the most important, test in that group. The fatigue test is likewise an important test in this same group. The second type or arbitrary tests are well represented by the impact test and transverse test. While these are important tests in the control of materials, they do not in their present stage provide data which can be directly used in design, hence their classification here as "arbitrary." These facts have probably been recognized throughout the long period of years in which tensile-test data have been used. Even today many engineers continue to apply tensile-test data for the design of members subjected to a wide variety of stress conditions. Modern thought has probably contributed most to setting limits on the conditions under which such data can be applied and has indicated those cases where more information is required for the best and most economical designs.

From the results of modern research, it is of interest to observe that fatigue strength is as closely related to tensile strength as it is to any other physical property. While this relationship varies over wide limits, designs subjected to cyclic or variable stress may be somewhat rationalized if based on the tensile strength. It is well known, however, that such an approach cannot be particularly accurate. Furthermore, it does not take into consideration the effect of stress concentration which can only be done by looking at the design problem from a wider viewpoint.

CODE FOR WORKING STRESSES

In attempting to prepare a code for working stresses, it is at once apparent that there are but few tests upon which to establish a sound foundation. In the theory of elasticity, stress and strain are treated from a three-dimensional aspect but most of our knowledge, concerning the behavior of materials, rests on the results of simple unidirectional tests. In this respect tensile and fatigue tests are the most important. This situation may, of course, be changed when more data on the behavior of materials under combined stresses become available.

In the following presentation, the choice of working stress based on the yield strength or endurance limit is considered. It is recognized that in failure by buckling, the critical stress rather than the yield strength is the governing factor. Such conditions have not to date been included in the code under discussion.

Accepting the tensile and fatigue tests as the basis of our reasoning, stresses are classified as either steady or variable. The generalized (1, 2, 3)[1] condition of variable stress as in Fig. 1 (*a*) may be considered as consisting of a steady stress σ_m and a variable stress σ_r. The case of a pulsating stress is represented in Fig. 1 (*b*) and a completely reversed stress in Fig. 1 (*c*). In the latter case $\sigma_r = \sigma_e$ = endurance limit for reversed stresses.

Materials are further classified as being either ductile or brittle. Obviously, the limiting conditions for the case of steady stress must either be the tensile or the compressive strength and, for that of variable stress, the endurance limit.[2] Or, if σ = tensile or compressive strength, and σ_e = endurance limit for reversed stresses, the variable stress $\sigma_r \not> \sigma_e$ and steady stress $\sigma_m \not> \sigma$.

For the case of a ductile material the limiting condition will be as represented by *OAC* in Fig. 2. The line of failure for certain materials lies above *AC* but for simplification this is taken as *AC*. Such an assumption is, however, on the safe side. Any stress condition which falls outside of *OAC* according to this reasoning, which excludes hardening due to plastic yield-

[1] Numbers in parentheses refer to the Bibliography at the end of the paper.

[2] This assumes that the range of stress begins to decrease when the mean stress of the cycle becomes compressive. This is true in general but some exceptions have been noted.

ing, will result in failure. The case represented by OAC_1 for compressive stresses is not so well clarified since in this case the criterion of failure is less definite. Certain experimental values do, however, conform to AC_1 for negative mean stresses.

In the case of steady stress for ductile materials, it is customary to take not the value of the tensile strength $\sigma = OC$ as the limiting stress but rather the value of the yield stress $\sigma_{yp} = OB$. This means that the zone of failure is now represented by OAB for positive mean stresses. As before, any stress condition within this area will not result in failure and this area will represent all combinations of stress varying from a steady stress OB to a variable stress OA.

This general approach to the problem of working stresses has much to commend it. Some notable exceptions in the case of helical springs have been noted by Zimmerli (4) which deserve mention. Heat-treated chrome-vanadium steel springs to give a tensile strength of 205,000 lb per sq in. indicated a torsional endurance range of 75,000 lb per sq in. for stresses varying from zero to a maximum, whereas a stainless-steel spring (17.4 per cent Cr, 8.9 per cent Ni) treated to give a tensile strength of 216,000 lb per sq in. only indicated a torsional endurance range of 29,000 lb per sq in. when tested under similar stress conditions. Probably, however, these discrepancies, not explained by Zimmerli, are due to residual stress or surface effects which might be traced from a study of the elastic part of the tensile test. In this discussion, the effects of plastic flow due to tensile overstrain have been neglected. Haigh (5), however, has shown that such overstrain can increase the maximum value of the variable stress to such a degree that the extreme value of $\sigma_r + \sigma_m$ approaches the tensile strength of the material. Some application of these ideas by Zimmerli to the improvement in helical springs by shot blasting will be mentioned later.

The foregoing reference is to ductile materials. For the case of brittle materials, the tensile and compressive strength must be regarded as the limits of failure but this case is complicated in addition by the fact that the properties of such materials in tension and compression are usually different.

This method also allows consideration being made of stress-concentration effects. It is well known that rapid changes in section of machine parts lead to stress concentration. It is also generally accepted that for ductile materials such stress concentrations are less dangerous for cases of steady stress than for cases of variable stress. With this understanding, factors of stress concentration established by photoelastic research are well known and can be applied to the variable stress σ_r, Fig. 1. The results obtained by the application of theoretical factors are, in cases of departure, on the safe side.

Fig. 3 which has been reproduced from Fig. 2 indicates the conditions of steady and variable stress, the line AB representing the assumed line of failure. Although AB represents the assumed line of failure, every engineer will choose a factor of safety in order to cover the discrepancies which might occur in the load determinations, in the stress calculations, and in the material (1, 2, 6). If this factor be taken as n then the design limitations will be set by line LM where $OL = \sigma_e/n$ and $OM = \sigma_{yp}/n$. The general case will then be determined by the coordinates of a point such as G where the steady stress σ_m is represented by OF and the variable stress σ_r by FG. Given the values of endurance limit and yield strength and a knowledge of the particular mode of stress variation, the values of the variable stress σ_r and the steady stress σ_m can easily be obtained by graphical means.

If a machine part be made of medium-carbon steel such that the yield strength $\sigma_{yp} = 42{,}000$ lb per sq in. and endurance limit $\sigma_e = 30{,}000$ lb per sq in., and this part be subjected to a stress varying from O to σ_{max} then, if the factor of safety n be

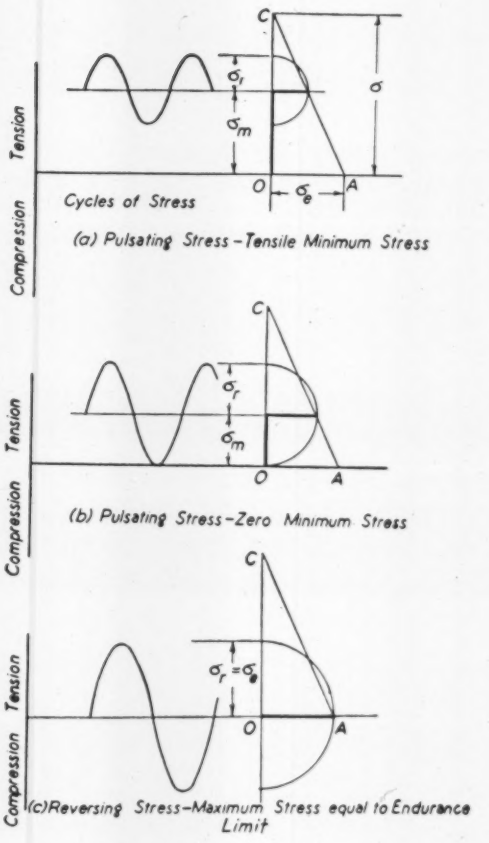

FIG. 1 GRAPHIC REPRESENTATION OF STEADY AND VARIABLE STRESSES; PULSATING STRESS; AND REVERSED STRESS

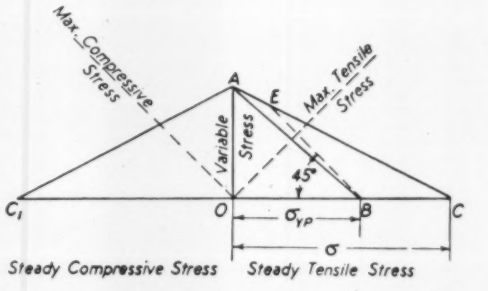

FIG. 2 LIMITING STRESS CONDITIONS FOR STEADY AND VARIABLE STRESSES

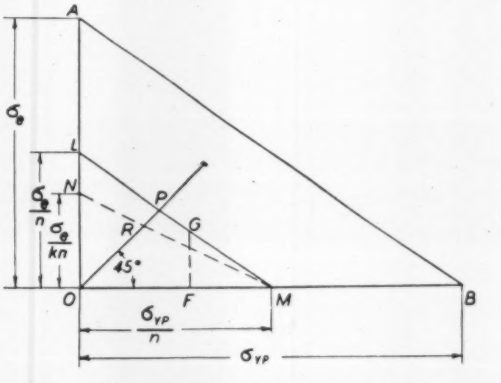

FIG. 3 GRAPHICAL METHOD OF DETERMINING MAGNITUDE OF STEADY AND VARIABLE STRESSES

taken as 2, triangles *OAB* and *OLM* can be drawn such that $OL = 30{,}000/2 = 15{,}000$ lb per sq in. and to the same scale $OM = 42{,}000/2 = 21{,}000$ lb per sq in. For this stress condition $\sigma_m = \sigma_r$ and this will be represented by a line *OP* drawn from *O* at 45 deg to *OB*. The coordinates of the point *P* of the intersection of this line with *LM* give the values of σ_m and σ_r. For this particular case $\sigma_m = 8750$ lb per sq in. and $\sigma_r = 8750$ lb per sq in. or $\sigma_{max} = \sigma_m + \sigma_r = 17{,}500$ lb per sq in.

CONSIDERATION OF STRESS CONCENTRATION

If now this same machine part has a change in section such that the stress-concentration factor k is 1.4, the same approach can be used to arrive at a satisfactory design. For tables of actual values of k, refer to work by Frocht (7) and Riggs (8).

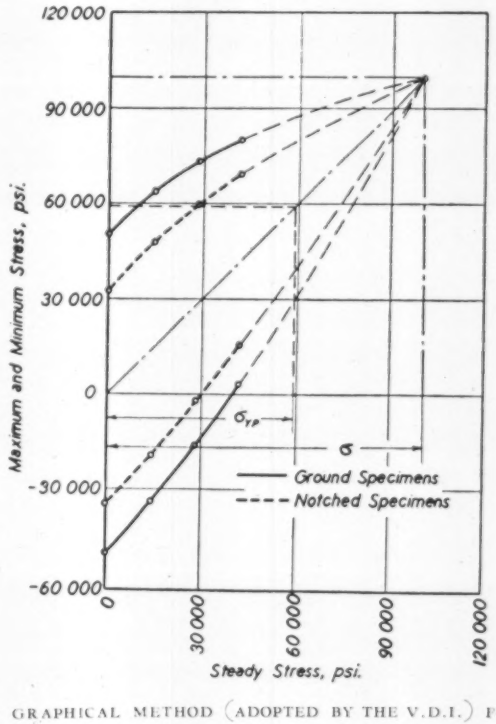

FIG. 4 GRAPHICAL METHOD (ADOPTED BY THE V.D.I.) FOR DETERMINING MAGNITUDE OF STEADY AND VARIABLE STRESSES

For such conditions, it is assumed that any correction for stress concentration need only be applied to the variable part of the stress. This assumption seems justified on the ground that stress concentration when applied to steady stress on ductile materials will only lead to local yielding and, hence, a more favorable stress distribution.

Applying these data to the case under consideration, point *N* is determined from the condition that $ON = \frac{\sigma_e}{kn} = \frac{30{,}000}{1.4 \times 2}$. The point *N* so obtained is joined with *M* and as before the coordinates of point *R* of intersection with the 45-deg line from *O* determine the values of σ_m as 7200 lb per sq in. and σ_r as 7200 lb per sq in. This means σ_{max} for this case becomes 14,400 lb per sq in., as compared with 17,500 lb per sq in. with no stress concentration. In other words, this method of approach provides the designer with a tool whereby the effects of stress concentration may be fully recognized in his design.

Steady and variable stress conditions can also be represented by a diagram, the ordinates of which are maximum-minimum stress and the abscissas the mean stress of the cycle. This is the method, as shown in Fig. 4, adopted by the Verein deutscher Ingenieure (9, 10, 11) in its design sheets. It has been found of considerable value in certain laboratories in this country. This method has the distinct advantage of showing at a glance the effects of stress concentration.

IMPORTANCE OF YIELD STRESS

The preceding brief summary of the present engineering viewpoint leaves many points on which more information is desired. In choosing the yield stress as the basis of failure for steady stress conditions are we on solid ground? This choice seems logical for those materials which have a definite yield point, but is the stress value corresponding to an extension of 0.2 per cent justified for materials such as copper or aluminum alloys which have no yield point in view of the known benefits of plastic flow? The contributions of N dai (12) and his associates, and Davis (13) have done much to clarify our understanding of yielding phenomena but much yet remains to be done. Since it is to be expected that work on combined stress will develop in future years, what should be the criterion of failure for such conditions? The beneficial effects of overstrain have already been mentioned. From the work which has been done on the shot blasting of helical springs, resulting in a very substantial increase[3] in the safe fatigue range under stress conditions which represent a steady torsional stress plus variable torsional stress, it may be that the choice of yield stress, as now defined, as the limit of failure for steady conditions is unduly conservative.

The importance which yield stress plays in the applications of materials may be shown in another way. Referring to Fig. 1 (*b*), it is apparent that, if the stress remains pulsating and does not become reversing

$$\sigma_m \gtrless \sigma_r$$

This means that a line *BE* drawn as in Fig. 2 at 45 deg to *OC* will satisfy conditions that $\sigma_m + \sigma_r = \sigma_{yp}$. Any point to the left of *E*, the point of intersection of fatigue line *CA*, will represent conditions where fatigue failure is likely to occur prior to yielding because $\sigma_m + \sigma_r < \sigma_{yp}$. Any point to the right of *E* will represent conditions where yielding is likely to occur prior to fatigue because $\sigma_m + \sigma_r > \sigma_{yp}$. In the case of an annealed 0.3 per cent carbon steel, the value of σ, σ_{yp}, σ_e, represented, respectively, by *OC*, *OB*, and *OA* will be of the order of 70,000 lb per sq in., 37,000 lb per sq in., and ±30,000 lb per sq in. (14). In the case of alloy steels the value of the yield stress σ_{yp} will be increased to a much greater percentage of the tensile strength than is the increase in endurance limit. For instance, for an oil-hardened and tempered $3\frac{1}{2}$ per cent Ni-Cr steel (14), the values of σ_{yp}, σ, and σ_e would be changed to 128,000 lb per sq in., 138,000 lb per sq in., and ±68,000 lb per sq in., respectively. Accordingly, using the same convention, point *E* in Fig. 2 will move nearer to *C*, increasing the possibilities of fatigue failures occurring before the yielding takes place (15). It is recognized that point *E* is only a rough approximation, since experiments show that fatigue failures may not take place until the stress has exceeded that at *E*. If, however, point *E* is taken this means that, in the case of a carbon steel, there is more likelihood of local yielding occurring, thereby allowing a redistribution of stress, than in the case of alloy steels. To apply this to an actual design problem, is it better to use a carbon steel in an aircraft-engine connecting-rod stud where the yield point is nearer to the fatigue strength or an alloy steel where the yield point is considerably in excess of the fatigue strength?

HIGH-YIELD-RATIO STEELS

All of these phases of the strength problem seem to be in-

[3] A safe range of +20,000 to +80,000 lb per sq in. increased to +20,000 to +120,000 lb per sq in. by shot blasting has been obtained by Zimmerli.

volved in a discussion of strength properties as shown by the tensile test. They also raise the question of the efficacy of high-yield-ratio steels under variable-stress conditions.

IMPORTANCE OF DUCTILITY

Regarding the question of ductility values obtained from the tensile test, engineers might classify ductile materials as those which show an elongation in the tensile test of 5 per cent and over and brittle materials as those which indicate less than 5 per cent. This is quite an arbitrary choice but obviously some line of demarcation between known ductile materials, such as soft steel and copper, and known brittle materials, such as cast iron, must be made in any rationalizing process. In regard to the value of ductility, which arbitrarily classifies the ductile and brittle materials, the engineer looks upon this as a safeguard against the effect of stress concentrations. Certain data (16), although very meager, are available to support this viewpoint. The new ideas regarding ductility which we are now obtaining from previous work of Ludwik (17) and the more recent contributions of MacGregor (18) may help to clarify some of our ideas regarding the importance of ductility values. On certain points engineers are clear. It is generally understood that so-called ductile materials can be made to behave as brittle materials and that the usual sliding failure obtained on such can become substantially a separation failure. Therefore, it may be in order not to classify materials as brittle or ductile but, as Nádai (12) and Timoshenko (6) have suggested, refer to the brittle or the ductile state of materials.

AIMS AND SCOPE OF SYMPOSIUM

In order to bring before the materials engineer the viewpoint of the designing engineer and to allow clarification of certain of the characteristics of the tensile test, some of which have been mentioned, the present Symposium is being organized.

The Symposium will consist of three papers dealing with the more fundamental aspects, the strength features, and the ductility features. The specific titles and authors are as follows:

1 "The Tensile Test," by C. W. MacGregor.

2 "The Strength Features of the Tensile Test," by F. B. Seely.

3 "The Ductility Features of the Tensile Test," by H. W. Gillett.

Arrangements have been made to have the papers preprinted and distributed considerably in advance of the date of presentation and it is to be hoped that a comprehensive discussion of each will result. If the Symposium and discussion develop better understanding of the behavior of materials leading to their better application the Committee will feel amply repaid for its efforts.

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Mudd

The CYCLE THEORY *of* COLONEL AYRES[1]

By DONALD S. TUCKER

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ENGINEERS have a peculiar interest in the cycles of business prosperity and depression. Other professions, such as medicine, law, and teaching, suffer diminutions of income with the rest of the community, but suffer only as the rest of the community suffers. Engineers suffer from depressions almost as much as do the producers of durable goods.

It is partly for this reason that the books reviewed on this page have included a considerable number of works on the various aspects of the business cycle; but there is also a second reason for this emphasis. The causes of business prosperity and depression have engaged the attention of analysts for nearly a century. This prolonged study has begun at last to yield significant results. Cycle literature is now almost as thrilling for the economist as Pasteur's discoveries were for medical men half a century ago.

The last century has witnessed a long succession of cycle theories. Each in turn has been propounded, elaborated, tested, and then either completely or in part discarded. Theories which blamed legislative action, foreign trade, sunspots, overproduction, variations in the quantity of money, underconsumption, rainfall, and other forces, have had their day, contributed their quota to our knowledge, and have then subsided. During the last decade, chief interest has been focused on the operations of finance.

STATISTICAL TEST FOR KEYNES THEORY

Some years ago an Englishman, J. Maynard Keynes, started a new line of attack which his critics seized upon and improved until we had finally a line of reasoning which seemed theoretically unanswerable. Its defect lay in its lack of statistical support. One part of the importance of the book here under review[2] lies in the fact that Colonel Ayres has devised a statistical test for this new piece of abstract theory. To apply this test, it was necessary to compile monthly totals of the new securities issued by American corporations throughout the period from 1863 to the present time. Since the earliest published record of such issues did not start until 1906, this was a task of some magnitude; but to economists the thrill derived from Colonel Ayres's work is that the figures he compiled by this effort vary from year to year and even from season to season almost precisely in the manner required by abstract theory. A hypothesis has thus been converted into an established principle.

Central elements of the theory thus established may be stated readily. Saving should be contrasted with investment. Saving by families and by corporations reduces the demand for goods and diminishes the volume of production. Investment expands the demand for goods and the magnitude of the national income. Investment does not necessarily occur as soon as money is saved. Saving is more orderly than investment. Variations in the speed of investment should prove, therefore, to be the chief determinant of the volume of business activity. Deficit spending by governments should have the same effect as real investment by business.

Colonel Ayres's book goes far beyond the establishment of this central thesis. His study is statistical. Regularity of sequence in time is accepted by him as proof. He presents thus six generalizations, of which the last five are less completely supported by his data than is his first. The fifth and sixth of his conclusions resemble so closely those of R. G. Hawtrey, that the Colonel's theory as a whole will probably be classified as belonging to the monetary school. Though his generalizations are thus eclectic in their origin, all six of his findings are worthy of attention here.

SIX GENERALIZATIONS

(1) Not only does the volume of industrial production move up and down with the preceding volume of new securities issued, the time interval by which finance precedes business also displays some regularity. On upswings the volume of business lags normally about six months behind the issues of new securities. On downswings this lag becomes on the average only about four months. In the seventy-year period which Colonel Ayres has examined, there was no single instance in which a large alteration in the sale of new securities has failed to entail a subsequent similar alteration of business volume. Issues of government securities exerted also the same effect as those of private corporations.

(2) The volume of new corporate securities tends normally to follow the prices of stocks. When the prices of common stocks are rising, the volume of new securities tends to rise. The peak of issues follows the peak of stock prices by about a month; the low point of new issues tends to follow the low point of stock prices by a similar interval.

(3) The prices of stocks tend to follow the prices of bonds. Use of moving averages would indicate that on the upswing the highest point of stock prices had followed the highest point of bond prices by about six months. On the downswing this interval is shortened so that the lowest point in stock prices tends to occur on the average only about one month later than the lowest level of bond prices.

(4) Bond prices tend to decline when rates of bank interest on commercial loans start to rise. During the period which Colonel Ayres examined, the highest rates of interest on commercial loans were followed usually after an interval of about three months by the lowest level of bond prices. On the upswing this characteristic lag became longer. Six months would normally elapse before the lowest level of commercial interest rates was followed by the highest level of bond prices.

(5) Bank rates of interest on commercial loans were until 1913 a function of the reserve ratios of the lending banks. When reserve ratios were increased, banks had more money available for lending and rates of interest therefore fell. Diminutions of this reserve ratio caused advances of the rate of interest.

(6) The reserve ratio of a commercial banking system is affected by the magnitude of its loans, but chiefly by the magnitude of its holdings of cash. Expanded business activity causes a subsequent flow of cash out from the banks and into the pockets of workers. Diminutions of business volume permit cash to flow back into the banks at some later date. The lowest rates of interest on commercial loans tend, therefore, to be found about eight months after the volume of business

[1] One of a series of reviews of current economic literature affecting engineering prepared by members of the department of economics and social science, Massachusetts Institute of Technology, at the request of the Management Division of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Opinions expressed are those of the reviewer.

[2] "Turning Points in Business Cycles," by Leonard P. Ayres, The Macmillan Company, New York, N. Y., 1939.

activity has reached its lowest level. The highest rates of interest on commercial loans tend to be found about four months after the preceding period of business prosperity has reached its peak.

Business cycles are therefore, in Colonel Ayres's opinion, self-perpetuating, though changing constantly in specific form. Business depression causes subsequent low rates of interest on commercial loans and these are followed by rising bond prices, advancing prices of common stocks, expansion of the volume of new securities, and subsequent expansion of business volume. Enlargement of the volume of production, on the other hand, causes advancing rates of commercial interest, and these in turn are followed by reductions in the prices of bonds and of stocks, curtailment of the issue of new securities, and subsequent contraction of business activity and income.

TYPICAL CYCLES

When cycles display this regular sequence of events, Colonel Ayres calls them "typical." Typical cycles occurred from 1831 to 1913. Since 1913 only one cycle has been typical. Colonel Ayres assigns this recent irregularity to the adoption of the Federal Reserve System and to other government activities, including war. Some economists may feel that there are also nongovernmental influences responsible for this recent irregularity. New rigidities have appeared in the prices of some commodities and of many services. For forty years, also, savings banks, insurance companies, investment trusts, and other corporations as well as private individuals have been growing more important as owners of capital funds. During the nineteenth century some prices may have been more flexible. Commercial banks were then almost the only important owners of capital available for investment. In this twentieth century the financial position of commercial banks is in the opinion of some economists no longer as important as formerly.

Prophecy is always dangerous. Future studies may lead to some correction of the figures presented by Colonel Ayres. To this reviewer it seems improbable, however, that his first or chief conclusion will ever be subjected to serious doubt. His conclusions with respect to the cycles characteristic of the period 1831–1913 seem also to be quite well established. Differences of opinion are most likely to occur with respect to his interpretation of the period 1913–1939, in which, Colonel Ayres admits, his typical cycle appeared but once. The activities of commercial banks and of governments are not the only variable elements in modern economic life. There may be general agreement that the operations of finance control the volume of business, but wide disagreement as to the forces which have controlled the operations of finance during the years since 1913.

PUMP-PRIMING RECOVERIES

In his discussion of pump-priming recoveries (chapter 11), Colonel Ayres may perhaps be guilty also of setting up two straw men for subsequent easy demolition. Would not even some opponents of pump priming object to the imputation of such naive simplicity to the Roosevelt administration? Were not the facts as well as the administration's apparent aims both more complex? For our purposes, however, the straw man erected in place of Mr. Keynes is more significant. It is true that Mr. Keynes's own exposition of his ideas is confusing and perhaps confused; but a rather simple illustration may perhaps present this issue with some fairness.

If goods are priced at $1 each, consumers can buy 100 goods monthly only if their incomes are $100. If incomes are diminished to $60, the full 100 goods can be sold only if average prices are diminished to 60 cents (the old-fashioned method of stimulating business recovery), or if consumers are given $40 (the new-fashioned plan, called pump priming). If, furthermore, consumers will not receive incomes of $100 from business until normal plant expansion is resumed; and if businessmen will not resume plant expansion until present facilities cease to be idle; and if, finally, the sale of 100 units in some month is necessary to eliminate this idleness, then a gift of $10 to consumers cannot be expected to start business on a self-perpetuating upward movement. The valid objection to pump priming is not incapacity to produce results. If the total quantity of money is sufficiently large, it seems quite possible that the pump could be started by the priming method, provided a nation were willing to pay the cost. Many economists object only to the cost.

Colonel Ayres is, however, correct in emphasizing the importance of the opportunity for business profits as well as in his contention that investment is affected by influences other than the volume of consumption. Businessmen will expand their facilities only if costs, including the cost of capital, are so low that they have confidence in future profits. If costs were extremely low, utilization of 70 per cent of existing plant might make some expansion seem desirable. Since costs, however, are still high, a more complete utilization of existing facilities and a consequent enhancement of some prices would presumably be necessary to stimulate recovery. Colonel Ayres is correct, therefore in asserting that the so-called acceleration principle is too simple to be correctly representative of present conditions; but the vigor of his own attack has led him beyond the bounds of established truth. This apparent defect in his reasoning may, however, arise from overvigorous statement of his argument, rather than from a real lack of appreciation by Colonel Ayres.

Though the colonel is obviously bitter against the New Deal, this book is no mere political screed. It is a work that deserves respect. Engineers will find it readable as well as thought-provoking. From this reviewer's point of view, its most serious defect lies in its failure to expand in some one connection a point which the Colonel makes quite correctly in several connections. Since reduction of the prices of manufactured goods and construction materials and diminution of wage rates in construction and manufacturing industries seem to be of peculiar importance now, the timeliness as well as the completeness of his work could have been improved by the insertion of a few paragraphs explaining the manner in which price equalization at some low level may facilitate the expansion of corporate issues and thus cause business prosperity. Can anyone compare the recession of 1920–1922 with that of 1929–1932 without recognizing how greatly recovery after the former period was facilitated by the greater universality of price reductions?

AT THE Swiss National Exhibition at Zurich, Switzerland, held in 1939, there was exhibited, according to a note in the *Sulzer Technical Review*, No. 4, 1939, a plant for ventilating and cooling rooms in a farmhouse by drawing considerable quantities of air out of the earth by means of a fan. This method has been used in Europe during recent years for ventilating workshops.

During winter, these plants may be used for drawing air from the earth for heating purposes, as for example, in garages where heating in the ordinary sense of the word is not necessary, but where the temperature of the air must nevertheless be kept from becoming too low. These installations consist of a simple fan unit which draws the air from a moderate depth underground and discharges it into the rooms to be warmed. This type of "heating" is possible because the temperature of air drawn from the earth is seldom less than 50 to 60 F. In other words, the heat obtained from a boiler that burns fuel can thus be replaced in this case by earth heat.

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

Day by Day

AS THIS is being written the war in Europe has entered its seventh month. The approach of spring finds a large section of the civilized world directed not so much to the hopes of rejuvenation, that have, since the beginning of time, influenced men's thoughts and actions, as to the fear of mass destruction that may be unleashed upon them. Mr. Sumner Welles is touring Europe as the personal representative of the President on a mission whose real purpose and significance can only be surmised. In this country an approaching national election has cast shadows of doubt and expectation over the domestic scene. In the Far East events are shaping whose meaning is obscured by distance and ignorance. The entire world finds itself in one of those phases of change that are more violently active in some periods of history than in others. Personal, national, and racial fortunes are in the balance.

Whether the scales tip toward peace or war the engineer will have his work to do. He may have to work as a useful political slave, or as he does now, a free man. In any event, forces stronger than men can control will be his taskmaster. Reconstruction, regardless of the agencies that promote it, is bound to come. If on no more rational basis than the mystical recurrence of spring and the long pageant of history, the evidence is on the side of reconstruction and a better world, even if it is not the reconstructed world each man fashions for himself in his dreams. The power of knowledge grows, and its conquests become more impressive, because knowledge is not predatory, ruthlessly destructive for selfish purposes, but fecund, producing more where there was less and distributing its produce ever more lavishly. Applied science is the greatest practical resource the world has, for it flourishes in bad times and in good times. It is the hope of reconstruction at home and abroad.

Modern Pioneers

Persistent busybodies are forever running up and down in the world flecked with the lather of wasted energy intent on personally conceived reforms they cannot possibly bring to pass without patient attention to obscure details. In their haste they pass by more plodding folk who are filled with the precious elixirs of curiosity, industry, and ambition and who concentrate, without too much thought for long-range plans for saving the human race, it is true, on the innumerable practical trifles that constitute the substance of material progress. The United States has been unusually blessed with men of this latter type—Franklin, Whitney, and their brother inventors—and for the last century and a half with a patent system under which invention has been tremendously stimulated.

Within the last month the National Association of Manufacturers directed attention to the 150th anniversary of the U. S. Patent system by a series of regional dinners held in several cities, that culminated in one at New York on February 27. Honored at these dinners were about 500 inventors who had been designated "Modern Pioneers." To be eligible for the award of this distinguished designation the inventor or research worker must have been granted a United States patent within the last 25 years. Nominations were made by representative manufacturers, executives, trade associations, and members of professional and engineering societies, and the selections were made by a committee on awards, of which Karl T. Compton, president, Massachusetts Institute of Technology and member A.S.M.E., was the chairman. Nineteen of these modern pioneers were designated "National Modern Pioneers," one of these being the du Pont Nylon group of eleven men. Of these nineteen, W. H. Carrier, A. V. de Forest, Henry Ford, and Charles F. Kettering are members of the A.S.M.E., Orville Wright is an honorary member A.S.M.E., and F. G. Cottrell and Irving Langmuir are medalists of the Society. The list of Modern Pioneers whose names appear in the 1940 A.S.M.E. Membership List follows:

ROGER W. ANDREWS, sales manager, Riley Stoker Corp., Worcester, Mass.

HAROLD C. T. AVERY, chief engineer, Marchant Calculating Co., San Francisco, Calif.

EDWARD BAUSCH, chairman of board, Bausch & Lomb Optical Co., Rochester, N. Y. (nonmember medalist)

R. L. BEERS, chief engineer, Detroit Stoker Co., Monroe, Mich.

CARL BREER, executive engineer, Chrysler Corp., Detroit, Mich.

A. F. BREITENSTEIN, chief engineer, The Geometric Tool Co., New Haven, Conn.

T. V. BUCKWALTER, vice-president, The Timken Roller Bearing Co., Canton, Ohio

EDWARD P. BULLARD, JR., president, The Bullard Co., Bridgeport, Conn.

C. A. CAMPBELL, engineer of tests, The New York Air Brake Co., Watertown, N. Y.

W. H. CARRIER, chairman of board, Carrier Corp., Syracuse, N. Y.

PHILIP H. CHASE, chief engineer, Philadelphia Elec. Co., Philadelphia, Pa.

WILLIAM A. CHRYST, consulting engineer, Delco Products, General Motors Corp., Dayton, Ohio

LOUIS A. CORNELIUS, president, Wolverine Brass Works, Grand Rapids, Mich.

F. G. COTTRELL, Washington, D. C. (nonmember medalist)

S. L. CLUETT, vice-president, Cluett, Peabody & Co., Inc., Troy, N. Y.

W. A. DARRAH, president, Continental Industrial Engineers, Inc., Chicago, Ill.

A. V. DE FOREST, professor of mechanical engineering, M.I.T., Cambridge, Mass.

GANO DUNN, president, J. G. White Engineering Corp., New York, N. Y.

LEWIS M. ELLISON, president, Ellison Draft Gage Co., Chicago, Ill.

G. H. EMERSON, chief of motive power and equipment, B.&O.R.R., Baltimore, Md.

GUSTAVE FAST, president, The Fast Bearing Co., Annapolis, Md.

EDWIN R. FELLOWS, Fellows Gear Shaper Co., Springfield, Vt.

HENRY FORD, founder, Ford Motor Company, Detroit, Mich.

CHARLES H. FOX, vice-chairman of board, Ahrens-Fox Fire Engine Co., Cincinnati, Ohio

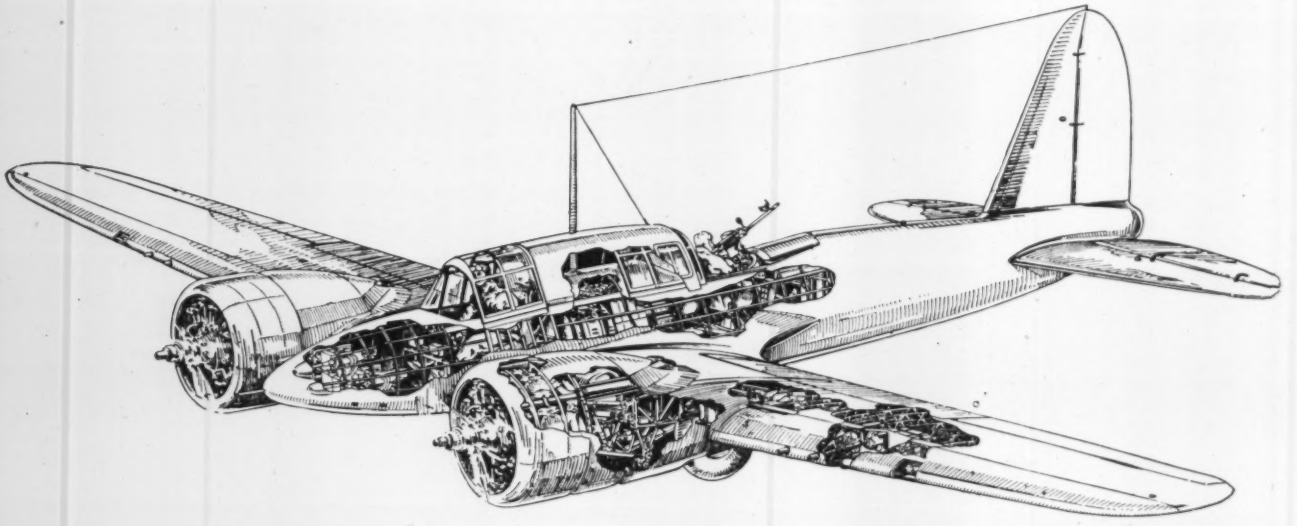
GEORGE H. GIBSON, consulting engineer, Montclair, N. J.

JAMES F. GLEASON, president, Gleason Works, Rochester, N. Y.
JOHN F. GRACE, engineer, Worthington Pump & Machinery Corp., Harrison, N. J.
R. E. HALL, director, Hall Laboratories, Inc., Pittsburgh, Pa.
FRANCIS HODGKINSON, consulting engineer, New York, N. Y.
WILLIAM C. HUEBNER, technical engineering counsel, Lanston Monotype Co., Philadelphia, Pa.
F. G. HUGHES, engineer, New Departure Division, General Motors Corp., Bristol, Conn.
D. S. JACOBUS, advisory engineer, Babcock & Wilcox Co., New York, N. Y.
C. F. KETTERING, vice-president, General Motors Corp., Detroit, Mich.
ALBERT KINGSBURY, president, Kingsbury Machine Works, Inc., Philadelphia, Pa.
IRVING LANGMUIR, General Electric Co., Schenectady, N. Y. (nonmember medalist)
ADOLPH LANGSNER, chief engineer, Eugene Dietzgen Co., Chicago, Ill.
THURE LARSSON, mechanical engineer, Norton Company, Worcester, Mass.
JAMES F. LINCOLN, president, The Lincoln Electric Co., Cleveland, Ohio
JOHN C. LINCOLN, chairman of board, The Lincoln Electric Co., Cleveland, Ohio
ALBERT J. LOEPSINGER, engineer, Grinnel Co., Providence, R. I.
SERN MADSEN, engineer and research director, Curtis Companies, Clinton, Iowa
W. H. MASON, director of research, Masonite Corp., Laurel, Miss.
THOMAS C. MCBRIDE, engineer, Worthington Pump & Machinery Corp., Harrison, N. J.
IRA E. MCCABE, chief engineer, Mercoid Co., Chicago, Ill.
FRANK E. MOORE, president, Mathews Conveyor Co., Elwood City, Pa.
WILLIAM D. MOORE, president, American Cast Iron Pipe Co., Birmingham, Ala.
E. A. MULLER, president, King Machine Tool Co., Cincinnati, Ohio
RAY C. NEWHOUSE, engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
MAURICE OLLEY, engineer, Rolls Royce Ltd., Detroit, Mich.
CARL G. OLSON, vice-president, Illinois Tool Works, Chicago, Ill.
JOSEPH S. PECKER, consulting engineer, Pitcairn Autogiro Co., Philadelphia, Pa.
KARL E. PEILER, vice-president, Hartford-Empire Co., Hartford, Conn.
A. L. PENNIMAN, general superintendent, Electric Div., Consolidated Gas, Electric Light, & Power Co., Baltimore, Md.
CHARLES H. PRANGE, vice-president and general manager, Austenal Labs., New York, N. Y.
WILLARD F. ROCKWELL, president, The Timken-Detroit Axle Co., Detroit, Mich.
HEYMAN ROSENBERG, chief engineer, Parker-Kalon Corp., New York, N. Y.
FRANK E. RUSSELL, mechanical engineer, Southern Pacific Co., San Francisco, Calif.
E. J. SWEETLAND, chairman of board, Oliver United Filters, Inc., Oakland, Calif.
EARL A. THOMPSON, engineer, General Motors Corp., Detroit, Mich.
JESSE G. VINCENT, engineer, Packard Motor Car Co., Detroit, Mich.
MARSDEN WARE, engineer, Packard Motor Car Co., Detroit, Mich.
WILLIAM M. WHITE, engineer, Allis-Chalmers Mfg. Co., Milwaukee, Wis.
ERNEST WILDHABER, engineer, Gleason Works, Rochester, N. Y.
ELMER E. WOODWARD, president, Woodward Governor Co., Rockford, Ill.
ORVILLE WRIGHT, Dayton, Ohio (honorary member)

Research Survey

A natural association of ideas leads from the 150th anniversary of the United States Patent System and the honoring of 500 Modern Pioneers to the attention that the National Resources Planning Board (formerly known as the National Resources Committee) is directing toward research in industry in a survey on this subject which it has asked the National Research Council to undertake. As noted in the brief report on the actions of the A.S.M.E. Executive Committee, to be found in the A.S.M.E. News section of this issue, C. E. Davies, secretary of the Society, has been authorized to participate with Harvey N. Davis, past-president, at the request of the National Research Council, in the preparation of a report on work performed by mechanical engineers in industrial research in the United States. Material for the report has been assembled, and the report will be submitted shortly.

As to the survey itself, Ross G. Harrison, chairman of the National Research Council, in a notice published in *Science*, Feb. 23, 1940, says that ". . . it is desired to visualize the significant trends which the development of research has taken through these laboratories in various industries, many of which in newer fields are based largely on the direct application of scientific knowledge to manufacture. Discussion of the present relation of research to the growth of a number of the major industries



DETAILED DRAWING OF CURTISS 76-D TWO-ENGINED FIGHTING AIRPLANE

(This American design, as shown in the February, 1940, issue of *Aviation*, has a full cantilever wing consisting of a center panel and two detachable outer panels. The all-metal fuselage is of semimonocoque construction covered with aluminum-alloy stressed skin. Besides the machine gun at the rear of the cockpit, the airplane carries four fixed .30-caliber machine guns in the nose and two in each of the wings.)

will be included. Another portion of the survey will deal with the extent to which the recognized disciplines of science—physics, chemistry, mathematics, metallurgy, the several fields of engineering, biology, and certain borderline fields—are applied in different industries. A history of the development of the research idea in industrial operations and certain economic aspects of the development of research in industry and a comparison of industrial research abroad with its growth in this country will also be included in the report.

"In effect, the occasion of this survey is an opportunity for industries in which science is an integral part to undertake a critical and constructive scrutiny of the present utilization of science in manufacturing, in communications, in transportation, and other fields of industrial activity. It is intended that the study be an untrammeled analysis of the situation, committed only to the purpose of encouraging the best use of science in relation to human welfare.

"To take charge of this survey the Council has appointed a committee of which Mr. F. W. Willard, of the Nassau Smelting and Refining Company, is chairman. The committee is composed largely of industrial executives and research directors and representatives of universities active in industrial research. The immediate direction of the survey has been placed by the Council in the hands of Mr. Raymond Stevens, vice-president of the firm of Arthur D. Little, Inc., of Cambridge, Massachusetts. With him will be associated Mr. Dexter North, of Washington, D. C., and Dr. Caryl P. Haskins, president of the Haskins Laboratories, in Schenectady, New York, as assistant directors of the survey. A score or more of forward-looking men representing the interests of industrial laboratories, universities, and special research institutions have been requested to prepare sections of the report. The report when approved by the Council is to be delivered to the National Resources Planning Board in printed form."

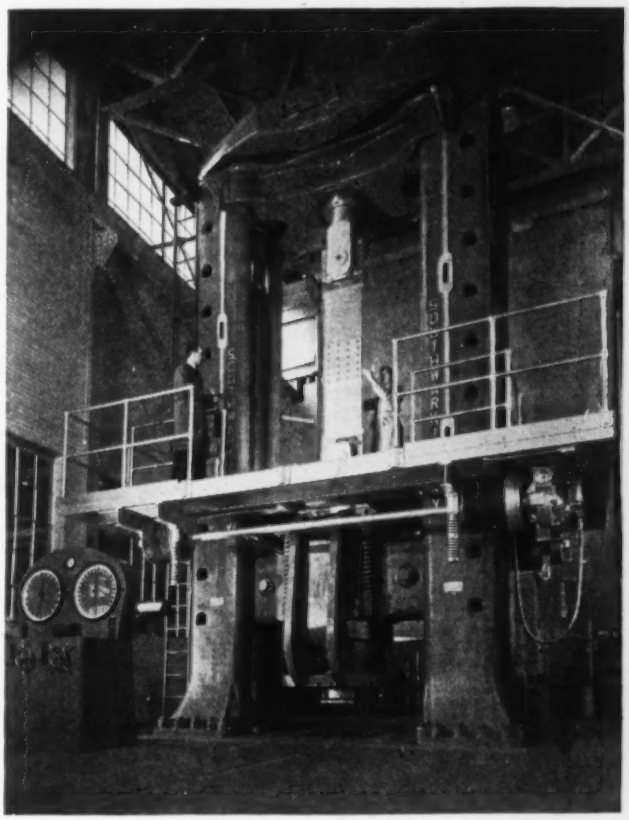
Iron Research

What another group, the Iron Alloys Committee, in its Alloys of Iron Research, organized in 1929 by The Engineering Foundation with the assistance of the American Institute of Mining and Metallurgical Engineers and the cooperation of nearly 90 companies, research institutions, federal bureaus, and technical societies (including the A.S.M.E.), has accomplished is briefly set forth in a ten-year progress report issued by The Engineering Foundation in January, 1940.

At a cost of $271,000 the committee has prepared 20,000 abstracts of 10,000 papers in at least 10 languages published from 1890 to date, from which 11 monographs, containing 5630 pages and one special volume on phase diagrams, have been issued. Four additional monographs are planned. Seven of the monographs are already in their second printing. The monographs so far published deal with alloys of iron and molybdenum, silicon, tungsten, copper, carbon (2 volumes), chromium (2 volumes, low and high chromium), and nickel, the metal iron, and principles of phase diagrams. Monographs in preparation will deal with alloys of iron and nickel (second volume, steels and cast iron), manganese, vanadium, and sulphur and phosphorus.

George B. Waterhouse, professor of metallurgy, Massachusetts Institute of Technology, is chairman and director of the Iron Alloys Committee. Serving with him are nine other members. Frank T. Sisco is metallurgist and editor, and John S. Marsh is physical metallurgist and associate editor of the committee.

The report closes with a statement that the monographs could be brought up to date, at a cost of approximately $15,000 per year, beginning in 1943, by publishing new editions or small supplementary volumes. Such a plan is recommended.



WORLD'S MOST POWERFUL COMPRESSION-TENSION TESTING MACHINE

(This huge piece of equipment, recently installed at the New Kensington plant of the Aluminum Company of America, is capable of exerting a force of 3,000,000 lb in compression and 1,000,000 lb in tension. While it is not the largest machine of its kind in the world, it is the most powerful, for it can exert these forces at speeds up to 36 in. per min. The precision machine, weighing 1500 tons, can also be operated as an extrusion, forging, or forming press. It is 40 ft, 4 in. high, of which 25 ft are above the floor line and the rest below. For testing large structural specimens, a pump delivering 18 gal of oil per min is driven by a 20-hp motor. A 300-hp motor delivering 270 gal per min is used for high-speed testing. In both instances, oil is delivered at a pressure of 1800 lb per sq in.)

Akroyd Engine

Light was shed on one of those trifling perplexities by a paper "Herbert Akroyd Stuart and the Development of the Heavy Oil Engine," presented to the Diesel Engine Users Association on Jan. 11, 1940, by T. Hornbuckle and A. K. Bruce. "Akroyd," say the authors, "was the maiden name of the inventor's mother, to whom he was deeply attached. It is believed that this was the reason why the name 'Akroyd' was given to the engine." They also quote the inventor's associate, W. J. Halloway to the effect that the by-product of a distillery was offered as a fuel for the Akroyd engine. "We used it," he said, "and the engine ran on it quite as well as it ran on paraffin. In fact we made it our standard fuel and we named it 'AVO' (Akroyd Vapourizing Oil)." And so the first heavy oil engine was known as the Akroyd, not the Stuart, engine.

Interest in Akroyd Stuart centers around this fact that his internal-combustion engine, which antedated Diesel's, bears a closer resemblance, in principle, to many engines that are now

called Diesels, than did Diesel's engine. Yet in England, and in the rest of the world, the name Diesel has become attached to practically every compression-ignition type of internal-combustion engine. In fact, such is the power of publicity, laymen are not only Diesel-conscious but also attach some mystic significance to the name. Even the authors of the paper under notice read their monograph before a Diesel-users group in a country where Diesel buses and Diesel lorries are popularly known.

Why did Akroyd Stuart lose out in this naming of the compression-ignition engine? In a discussion of the Hornbuckle-Bruce paper, a copy of which was graciously sent to MECHANICAL ENGINEERING by its author, Col. Oliver Field Allen, member A.S.M.E., wrote:

We thus see that Stuart first applied the direct injection of fuel which has now become almost universal in compression-ignition engines of all types; that he also anticipated various types of precombustion chambers which are now extensively used in the automotive Diesel engines; and that he actually made fuel-oil engines which worked some years before Diesel produced a working oil engine.

On the other hand, Diesel started with a more efficient type which was capable of being applied to large units, which insured fuel economies never secured with the vaporizer or combustion-chamber type of engine, and which would run reliably under wide variations in load.

In the last 10 years of the nineteenth century, there was no demand for small high-speed internal-combustion engines. There was a real demand for large heavy-oil engines for power plants both on land and at sea. Diesel's work laid the foundation for the large-scale production of such engines in many countries. These large engines naturally attracted attention and this may be a reason why the heavy-oil engine has come to be generally spoken of as a Diesel engine and the fuels best suited to its use called Diesel fuels.

In the first 20 years of the twentieth century, the large Diesel engines just referred to were extensively used and it is only during the last 20 years that the small high-speed, lightweight engine has come into being and brought with it a revival of the direct injection of fuel and in some instances the vaporizer or precombustion chamber.

While Stuart was alive, it was practicable to make fuel pumps and injectors acceptable for direct injection with the relatively low pressures employed in his Akroyd engine. It was not then practicable to build injection pumps, injectors, and nozzles which would properly introduce the fuel by direct injection into the high-temperature, high-pressure air masses of the Diesel engine. It was practicable to compress air to the required pressures; the air blast assured atomization of the heavy oils and consequently air injection was employed.

Twenty years later, engineers had learned how to build injection pumps and appurtenances for direct injection at high pressures and the added economy naturally caused their adoption even in the largest Diesels while the simplicity resulting from the elimination of air-injection equipment helped to make feasible the small high-speed compression-ignition engine.

It would seem that Stuart's work was fundamental and gave to the world means now largely employed in thousands of small high-speed engines, but that the needs of the times and design and manufacturing limitations delayed application of his inventions for about a generation.

On the other hand, Diesel's inventions provided for the rapid development of the large oil-engine power plants and set the pace for high thermal efficiency.

Modern developments requiring higher speeds for both pistons and shaft rotation with much shorter time for ignition and expansion have resulted in the general elimination of the Diesel cycle of combustion at approximately constant pressure, and the so-called Diesel engine of today is largely an engine having explosive burning with high peak pressures. Diesel would hardly recognize many of today's engines bearing his name and might resent the almost complete abandonment of the Diesel cycle. Stuart might be equally surprised to see oil engines of over-all dimensions approximating those he made, but with explosive burning; compression pressures 20 times those he used; indicator mean effective pressures four to five times his; rotative speeds ten times, and piston speeds three times those of his engines; fuel consumption about one third: and output per pound of engine as much as 100 times as great.

Amplidyne Generator

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

DURING the winter convention of the American Institute of Electrical Engineers held in New York City, Jan. 22–26, 1940, several papers were presented on the theory, design characteristics, and applications in industry of the amplidyne generator or dynamoelectric amplifier, a device which may be used for controlling large amounts of electric power. Although at first glance it looks like an electric motor or generator, the amplidyne generator is, to all intents and purposes, a control device. It is, in a sense, similar to radio-amplifier tubes. Just as certain vacuum tubes, through the control of minute amounts of electric power, can control the flow of tremendous amounts of power in other electric equipment, so the amplidyne generator can amplify hundreds or even thousands of times the variations in the power impressed upon it.

Specifically, the amplidyne generator is a motor-driven compensated generator characterized by an extra set of short-circuited brushes for each set of poles. These short-circuited brushes are usually set at right angles to the power brushes. Its principal electrical elements, as shown in Fig. 1, are a control field, a short-circuit set of brushes for the armature, and an output circuit from the armature including a compensating winding. The first stage of amplification is from the control field to the short-circuited brushes and the second stage is from the short-circuited brushes to the power brushes. The over-all amplification is the product of an amplification of about 100 to

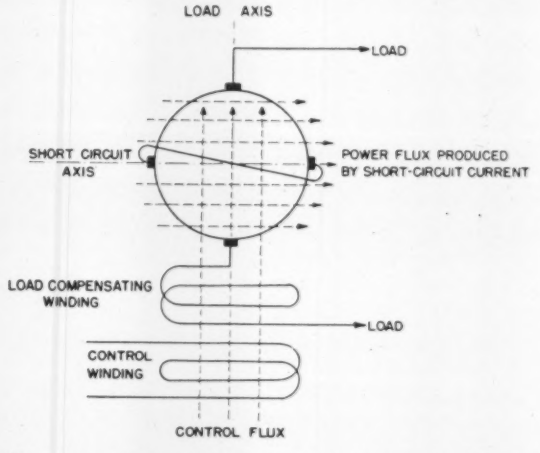


FIG. 1 FUNCTIONAL DIAGRAM OF THE AMPLIDYNE GENERATOR

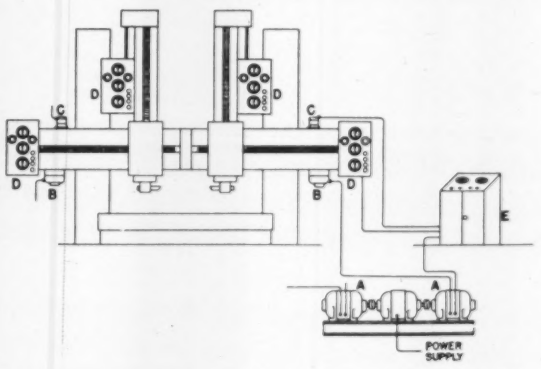


FIG. 2 ARRANGEMENT OF AMPLIDYNE CONTROL EQUIPMENT FOR AUTOMATIC POSITIONING OF CUTTING HEADS ON A BORING MILL (*A*, Amplidyne generators; *B*, control motors; *C*, pilot generators; *D*, dial indicators and limit switches; and *E*, main control cabinet.)

1 between the input winding and the short-circuit axis and another of 100 to 1 between the short-circuit axis and the output axis.

In the field of machine tools the amplidyne generator has been applied to a multiple-head boring mill (see Fig. 2) as a means of obtaining rapid and accurate positioning of the cutting tool. In this instance, the operator presets the next cut to be made by means of dials which indicate feet, inches, and thousandths of inches. When one cut is completed, he clutches a motor, presses a button, and the cutting tool is automatically positioned for the next cut.

In the steel industry, the device has been successfully used to control the speed of reeling of continuous steel strip; for obtaining constant tension and uniform strip speed on steel-strip polishing apparatus; as a means of synchronizing the speed of flying shears with that of the last stand of rolls on hot strip mills; and for controlling the excitation of large synchronous motors driving structural-steel mills. The amplidyne generator has been applied to paper machines with the result that both light and heavy grades of paper can be made on the same machine uniformly and with a minimum of waste. In the same industry, it has also been used in conjunction with photoelectric equipment to maintain exact register of paper moving rapidly through rewinding machines.

Control of Diesel Smoke

SOCIETY OF AUTOMOTIVE ENGINEERS

ACCEPTANCE of Diesel engines as automotive power units in this country, particularly for bus service, has been retarded to a considerable extent because of the association of smoky exhausts with the compression-ignition engine. In London, according to a paper presented at the annual meeting of the Society of Automotive Engineers, in Detroit, Jan. 15–19, 1940, written by W. W. Manville, G. H. Cloud, A. J. Blackwood, and W. J. Sweeney, the buses are not allowed on the streets if they are smoking and, naturally, there is no complaint. They even use fuels which, in many instances, would smoke excessively in this country. In order to discover methods of making American Diesel buses as clean in operation as the English ones, the authors made a study as to ways of preventing smoke.

They studied the effect of operating conditions, the relation of fuel characteristics to smoking, correlation of laboratory and road test data, and methods of controlling smoking. Considering all phases of their investigation, they conclude that the ultimate solution of the automotive Diesel smoke problem rests in mutual recognition by the engine builder, the equipment operator, and the fuel supplier that the problem is one requiring cooperative effort. While numerous phases of the Diesel smoke problem remain to be examined, the status of the investigations conducted to date would appear to justify certain well-defined conclusions.

In cases where either design, maintenance, or adjustment fail to accomplish the degree of smoke control desired, improvement can be brought about by the use of lighter fuels of suitable ignition quality. However, this is accomplished by some reduction in power and a loss in fuel economy. It would appear more desirable to take the power loss required for smoke control by means of resetting smoke-stop adjustment while retaining the advantage from an economy standpoint of the higher heat energy in a gallon of the heavier fuel. On engines having no smoke stop, the desired result can be obtained by a suitable stop or turnbuckle arrangement in the throttle connection to the cab controls.

This study on smoking has indicated that the effect of fuel characteristics is secondary to engine design, condition, and adjustment. This is substantiated by the buses operating in London which develop no objectionable smoke on 55–60 cetane number fuels of 550 F mid-boiling point. The explanation lies not in their being better engines than the American ones, but rather that they install oversize units such that, for the power required, they can set the smoke stop well down from the critical power point.

In so far as the fuel itself is concerned, the effect of cetane number on smoke is less important than the effect of volatility except in cases where the ignition quality of the fuel is below the minimum demanded by considerations of roughness and cold starting.

Safety Fuels

SOCIETY OF AUTOMOTIVE ENGINEERS

THE use of relatively nonvolatile gasolines in aircraft for the specific purpose of reducing fire hazard was first introduced several years ago, but development was discontinued at that time owing to certain obstacles which arose regarding suitable fuel-injection equipment, increased fuel costs, and availability of the proper fuel. During the last few years there has been a renewed interest in safety fuels, owing principally to the introduction of large flying units and an increased attempt to improve safety from fire both in operation and fuel handling. Another contribution to this renewed interest has been numerous mechanical improvements in engines and fuel-injection systems. Suitable fuels have also become more generally available.

With this in mind, the Society of Automotive Engineers sponsored a session on safety fuels at its annual meeting in Detroit, Mich., Jan. 15–19, 1940. Among the three papers presented was one by R. E. Ellis and W. J. Sweeney in which they discussed the availability and characteristics of aviation safety fuels. According to them, there are two general types of safety fuels of high octane number. The aromatic type is immediately available from selected crudes through the application of proved methods of solvent extraction. Supplies of material of this can also be augmented by hydrocarbon conversion processes, such as thermal and catalytic reforming, dehydrogenation, destructive hydrogenation, catalytic cracking, and vapor-phase cracking. The paraffinic type of suitable octane number for aviation use is not available in any presently known crude oils. Therefore, the paraffinic safety fuels will be of necessity all synthetic products, comparable to the blending agents now used in aviation gasoline, namely isooctane, hydrocodimer, alkylate, neohexane, etc.

Properties specified obviously control the availability of safety fuels. In a safety fuel, it must be assumed that the flash point is important and 100 F minimum temperature has been justifiably chosen as desirable, based on a mass of industrial experience on the handling of solvents, contrasted with gasolines of below-room-temperature flash points (as low as —30 F). While flash is primarily dictated by the initial boiling point, the latter can be lowered while maintaining the same flash if the boiling range is increased. An initial boiling point of about 280 F and upward, depending on the distillation range, will be necessary to meet a flash-point requirement of 100 F. With such a fuel, satisfactory operation in a normally carbureted engine is difficult and the problem of the engine designer is to develop a fuel system which will handle efficiently fuels of this initial boiling point, with as wide a boiling range as possible.

All possible types of aromatic fuels have not been investigated but those that are now available have octane numbers of 85 to 95 clear. Lead susceptibility is not particularly good but 100 octane has been reached with 3 cc of lead. The picture on the availability of paraffinic type of safety fuels is not so clear as that of the aromatic type. Predictions involve the estimation of the raw materials available and forecasts on the efficiencies of the current available processes that will make them. At present it appears that high-octane-number safety fuels of the paraffinic type will be made, at least in part, by synthetic methods using refinery olefinic gases and refinery and field isobutane. These safety fuels can be expected to reach 85 to 100 octane number, since they will be used as such rather than blended in lower-octane-number virgin stocks, as is the case at present with blending agents of normal volatility. With lead, of course, they will go higher, and have good lead susceptibility.

At present there are differences in opinion as to the relative performance of these two classes of hydrocarbons in full-scale operation. Aviation fuels containing substantial amounts of aromatics have been considered by some to be unacceptable for aircraft engines in the United States; whereas, such aromatic fuels have been regarded highly in Europe. Single-cylinder and full-scale engine tests recently carried out in this country show that partially aromatic fuels give over-all performance at least equivalent to the best paraffinic-type fuels. In view of this, aromatic safety fuels may show the same trend toward giving better full-scale engine performance.

Since the major argument for safety fuels is one of safety, it is obvious that experimental work must continue on the determination of the properties which contribute to reduction of explosion and fire hazard. One of these properties appears to be auto-ignition temperature, and there is some indication that aromatic-type fuels of a given boiling point have a higher ignition temperature than paraffinic fuels.

Efficient Burning of Wood

VARIOUS SOURCES

WOOD is staging a comeback as a fuel through the production of wood-burning appliances designed on new principles for which high efficiencies are claimed. Inadequate supplies of coal and the necessity of making use of timber which is useless for lumber or pulp purposes has stimulated this development, especially in Sweden and Germany. It is reported that in Sweden many ministerial and other public buildings are centrally heated by means of wood-using furnaces of the domestic hot-water type. In Canada, the Bureau of Mines has been conducting tests on domestic-type wood-burning heaters and hot-water boilers, including some made in Sweden. Developments in the United States have been more recent, especially in New England where millions of cords of wood are now going to waste as a result of the hurricane of 1938.

All of these new wood-using appliances operate on the so-called principle of "slow-combustion." To accomplish this, the heater or furnace is made as airtight as possible and fitted with closely controlled dampers. A long travel for the products of combustion is provided within the furnace itself, thus insuring that, as nearly as possible, complete combustion takes place before the gases escape into the chimney. The units have large magazines which require replenishing only two or three times a day. The burning of the solid wood is confined to a small area near the base of the magazine, but the combustion of the gases which are formed takes place in separate chambers located at the rear, sides, or front of the fuel magazine. If the furnace is correctly designed and operated, combustion is practically complete and there is no deposit of soot or creosote on the flues.

In a series of tests carried out by C. E. Baltzer and E. S. Malloch, division of fuels, Canadian Bureau of Mines, and reported in the Bureau's Memorandum No. 73 issued in December, 1939, three domestic-type wood-burning hot-water boilers, one made in Canada and the other two in Sweden, were used. The specifications for each boiler and the salient results of the tests, using average maple firewood, are briefly summarized in Table 1. Sectional views of the three boilers are shown in Fig. 3.

At the request of the Connecticut Forest and Park Association, Lauren E. Seeley, member A.S.M.E., conducted some experiments at Yale University on a small cast-iron wood-burning stove imported from Germany. Starting with this German model, Professor Seeley designed a heater specially adapted to American needs, which is now being produced and sold for about $50 by a stove manufacturer. A description of the 350-lb, cast-iron heater appears in *American Forests* for January, 1940.

The heater uses trimmings which may be obtained from lumbering and sawmill operations or from the "weeding" operations on the family woodlot. Chunks are not required since the unit will operate best on pieces below four inches in diameter. With its magazine or wood box compactly filled, the heater generates about 40,000 Btu per hr for an eight-hour period without attention. This heat is sufficient to take care of two to three rooms, depending upon size and arrangement.

Inside the heater there is a storage space or wood box which is 17 in. long (for 16-in. wood), 12 in. wide, and 19 in. deep.

TABLE 1 WOOD-BURNING BOILER RATINGS, SPECIFICATIONS, AND TEST RESULTS

Items	Boiler No. 1 Canadian conventional, round, cast-iron type	Boiler No. 2 Swedish downdraft, square, welded-steel-plate type	Boiler No. 3 Swedish underburning, square, cast, sectional type
Rated capacity, Btu per hr	132000	138880	124990
Average rating ft of water radiation, sq ft	880	926	833
Nominal grating area, sq ft	3.4	4.5	2.9
Area of heating surface, sq ft	32.4	53.8	48.4
Volume of fuel magazine, cu ft	5.4[a]	12.0	8.1
Gross shipping weight, lb	1630	1740	2343
Retail cost at Ottawa, Canada	$160	$305[b]	$265[b]
Duration of trials, hr	120	120	120
Interval between firings (average) hr	2.00	5.62	6.00
Dry fuel burned:			
Per hour, lb	17.6	19.6	18.8
Per therm[c] delivered to cooling water, lb	20.59	23.64	22.76
Temperature, flue gases at boiler outlet, F	439	277	327
Carbon-dioxide volume in flue gases at boiler outlet, per cent	12.4	6.7	8.4
Excess air, per cent	52	150	115
Draft at boiler outlet, in. water gage	0.012	0.146	0.042
Heat transmitted to cooling water:			
Per hour, Btu per hr	85487	83093	82434
Per lb of dry fuel burned, Btu per hr	4856	4233	4393
Rated boiler capacity developed, per cent	64.8	59.8	65.9
Over-all thermal efficiency, dry fuel basis, per cent	57.3	50.9	52.9

[a] Volume, grate to top of firepot.
[b] Price based on Swedish Krona at 25.77 cents Canadian.
[c] Therm equals 100,000 Btu.

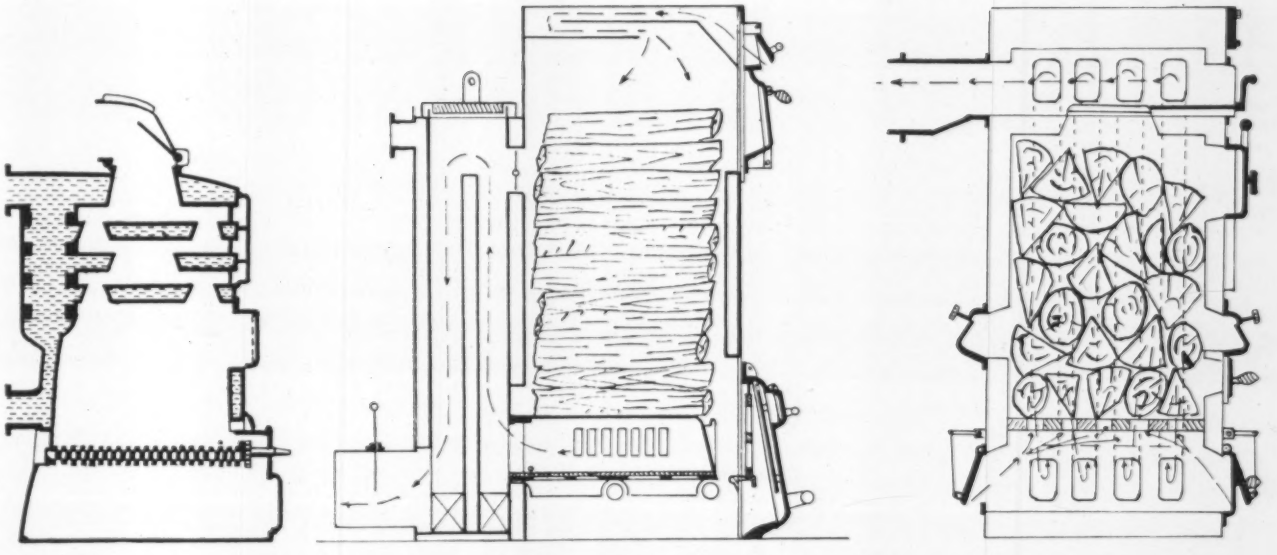


FIG. 3 SECTIONAL VIEWS OF WOOD-BURNING BOILERS
(Left to right; boiler No. 1 manufactured in Canada, and boilers Nos. 2 and 3 made in Sweden.)

At the bottom of the box is a special grate and, on the top, a lid which may be opened for recharging. The front side of the box does not extend clear down to the grate but stops about 2 in. above it. Thus the box is not completely enclosed. All of the gases from the burning wood must pass in a horizontal direction to this front opening. The effect is to confine the combustion zone of the wood to the bottom of the box just a few inches above the grate. When the gases have left the wood box at the bottom, highly heated but not completely burned, they pass into small passageways which may be called combustion ports. Secondary air from the ashpit passes into some tuyères which heat the air and inject it into the combustion ports. This causes the wood gases to burn.

Then the gases from the combustion ports rise through a vertical flue formed by the front of the heater and the front side of the wood box that is open just above the grate as previously described. The gases then travel back across the top of the heater between the top lid and the wood-box lid to a smoke outlet. The author recommends that the smoke-pipe connections be short, tight, and that they pitch toward the chimney if possible, and that no smoke-pipe damper be used. The air damper is enough to control the rate of burning and during refueling the gas venting is more effective.

Product Surface Finishing

ELECTRICAL MANUFACTURING

WITHIN the last two years notable advances have taken place in the application of enamels and lacquers to the surfaces of various products. There has also been a definite tendency in the direction of mechanizing finishing processes. These better finishes and faster methods are covered by G. Klinkenstein in an article that appears in *Electrical Manufacturing* for March, 1940.

As a result of intensive research, a variety of "high-speed" enamels came into prominence about two years ago. These enamels air dry, out of dust, rapidly and can be baked hard and ready for wrapping and shipment without danger of paper printing with the following baking schedules: 5 min at 350 F; 10 min at 325 F; 30 min at 300 F; and 60 min at 275 F. A longer baking period is employed at lower temperatures to provide a finer and better finish. Besides permitting rapid production, these enamels provide finishes of the highest quality, with good gloss, excellent color retention, unsurpassed hardness, durability, and resistance to marring, moisture, and the action of household chemicals. They can be obtained in clear, white, black, and most colors, with both opaque and transparent pigments, with or without bronze powders, and for use on all metals, including zinc, as well as on plastics. They are usually applied by spraying only.

Wrinkle finishes have long been popular because with their use rough metal surfaces can be given a durable and attractive finish with a single baked coat. Available in almost all opaque colors, including white, brilliant reds, blues, and other light colors, soft pastel shades, transparent colors, and clear, wrinkle finishes are being applied to an increased number of products. Several grades are obtainable, varying in the character of the wrinkle structure produced and the baking schedule, as follows:

Wrinkle structure	One-hour baking schedule
Fine	Low heat, 150 to 200 F
Fine	Medium heat, 225 to 250 F
Medium	Low heat, 150 to 200 F
Medium	Medium heat, 225 to 250 F
Medium	Medium heat, 225 to 250 F

Of these grades, those giving fine and medium structures with a medium heat schedule are the ones chiefly used for quantity production. Air-drying grades are also available, but these are not recommended because they produce a finish that is greatly inferior to a baked finish. Properly baked wrinkle finishes are tough and durable and will not be noticeably affected by gasoline, kerosene, carbon tetrachloride, alcohol, soda solution, milk, or butter.

When lacquer was first developed for finishing, it could be applied only in very thin films and was suitable chiefly for protecting polished brass, copper, silver, and other metal surfaces from corrosion. Later research developed lacquer bases of low viscosity, which made it possible to apply relatively thick lacquer coats with a single application. During the last year, another step in this same direction has been taken. It has long been known that lacquers which are too viscid to spray at normal room temperatures can be rendered thin enough for application if heated, and advantage has been taken of this fact to produce lacquers giving still thicker coatings. In the hot-lacquer process, lacquer heated to 150 to 160 F in a special

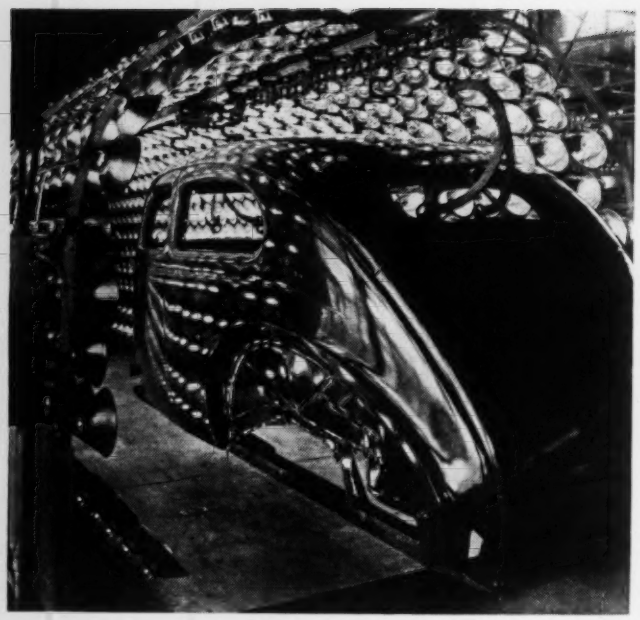


FIG. 4 INFRARED-RAY LAMPS IN GOLD-PLATED REFLECTORS BAKING FINISH ON AUTOMOBILE BODY

container is sprayed on the product with a special gun. Neither the product nor the gun has to be heated, but the gun has to be so designed that the heated lacquer flows through it continuously without cooling down.

To meet the demand for combinations of polished chromium and colors, several different finishing processes have been developed. These include: (1) Dipping chromium-plated products in a special alkali solution, which roughens the surface slightly, and then applying lacquer enamel where wanted; (2) coating the chromium-plated surfaces to be colored with a special clear chromium primer, then baking and applying the lacquer enamel to the covered surfaces; and (3) finishing, before plating, the portions of the product to be colored with a finish that will withstand the chromium bath, and then chrome plating the exposed metal surfaces.

Another fairly recent step in the direction of speeding up production is the development of primers and fillers which dry very rapidly. These materials are taking the place of those which must be allowed to stand a relatively long time before further work can be done on the product.

A line of special lacquers which color zinc and other "white" metal products to resemble copper, brass, bronze, processed aluminum, and other metals, has found wide use in the electrical industry and has greatly increased the usefulness of zinc and aluminum die castings.

When a centralized finishing-material mixing system is used, each finish is mixed in large tanks at a central point and then circulated through a pipe to all spraying booths. In some systems, as many as 20 different kinds of finishes are thus piped to the sprayers, who merely attach their guns to the outlet supplying the particular finish they desire to use. Another method of finishing products in large quantities involves refinements in the use of conveyers for handling several or all steps in the finishing process. In a fully developed system of this sort, products ready for finishing are hung on a conveyer, which then carries them through one or more dipping tanks, or past a series of automatic spray heads, and through the necessary ovens, and delivers them ready for packing at the other end.

Infrared-ray lamps are now used for baking finishes. In this system, the heater consists of a bank of 250-watt electric lamps with a low output of visible light and relatively high output of infrared heating rays (see Fig. 4). Special advantages claimed for this heating process include more rapid baking, baking the film of finish from the inside out, very short warming-up periods, little wasted heat to make the drying room uncomfortable, and a fraction of the space needed by fuel-fired ovens.

Though by no means new, centrifuging is mentioned here because it finishes a variety of small parts and products so economically that its use has greatly increased in the last few years. In this process, as carried out by one type of machine, the products to be finished are placed in a basket in the upper part of the centrifuging machine and the cover is clamped down. The basket is first lowered into a tank of finishing material located in the lower part of the machine, then raised, and finally rotated at high speed, first in one direction and then in the other. This rapid spinning and quick reversing forces the finishing material into the pores of the products under considerable pressure, returns the excess material to the tank, and insures an even coat free from indentations. After centrifuging, the basket is removed and the products are dried in an oven or otherwise.

Locomotive-Tire Failures

THE INSTITUTION OF MECHANICAL ENGINEERS

DURING the last five years a detailed and comprehensive investigation has been made into the causes of locomotive-tire failures on the London, Midland and Scottish Railway. As described by C. W. Newberry in a paper published by The Institution of Mechanical Engineers (Great Britain) in its Proceedings, January, 1940, the problem has been attacked along two directions: (1) To ascertain the cause of each particular failure as it occurred, and (2) to discover general relationships between effect and cause, and hence to suggest means whereby the possibility of tire failures could be reduced. Under the first of these heads examples are given of individual investigations covering a fatigue-flawed tire, and one that had failed as the result of defective material.

In association with the general problem, a number of auxiliary experimental investigations have been directed to the improvement of the wheel-tire assembly, and reference is made to the possibility of reducing wheel-rim distortion during the welding of defective spokes, and to the increased effective fatigue strength of the tire that can be achieved by suitable surface finish of the tire bore.

Each year a statistical review has been made of all locomotive-tire failures throughout the company's system, and has shown that until recently, the predominant failure was the fatigue type of crack, originating near the tire bore. The information so obtained has enabled many of the factors which are believed to promote the development of fatigue failure to be examined critically and their responsibility assessed. Thus, stress-raising features such as stud and rivet fastenings, and deviations from trueness of the wheel center have proved important contributory factors in many cases. Driving wheels appear to be nearly twice as susceptible to fatigue as nondriving coupled wheels, and leading coupled wheels twice as liable as others, while between different sizes of coupled wheels there is a marked tendency for fatigue flaws to occur more readily the larger the wheel diameter. There is evidence to suggest that, in addition to tread forces, impacts from wing and check rails on the back of the tire flange are among the most important service forces leading to fatigue stresses.

In conclusion, it is of interest to note the continued decrease in fatigue failures that has taken place during the progress of the investigation. It is particularly significant that, so far, no fatigue failure has been known to occur on any tire that has been bored with a carbide tool, nor has there been any failure of a tire associated with the Gibson ring fastening or the modified wheel rim with the balance weight cast separately. It is confidently expected that the fatigue strength of the wheel assembly has now been raised sufficiently to make fatigue flaws in locomotive tires a rare occurrence.

Photography in Engineering

JOURNAL OF THE JUNIOR INSTITUTION OF ENGINEERS (LONDON)

PHOTOGRAPHY has become one of the most valuable tools of engineering. Many of the advances made so far in alloys, machine design, high-pressure and high-temperature boilers and turbines, time and motion study, and other fields have been due to the use of photography in one form or another. Some of these applications are described in an article by A. H. Styring, which appears in the December, 1939, *Journal of the Junior Institution of Engineers*. Because the applications are so varied and far-reaching, the author touches upon only a few of the most outstanding ones, namely, infrared photography, photography by polarized light, X-ray photography, and high-speed photography. An abstract of the paper follows:

Infrared sensitive materials have proved of the greatest value in spectroscopy and astronomy. When photographing at great distances, the best results are obtained with infrared materials and filters. The rays are less easily scattered by water and dust particles in the intervening atmosphere than are the shorter rays in the normal visibility range. The power of haze penetration is important and has an engineering application. Research is in progress for the adaptation of infrared sensitive materials for navigational and military purposes. Good work has been done in permitting vision of objects invisible to the naked eye up to six miles, and distances up to 20 miles have been claimed.

It is possible to reveal by infrared photography many structures invisible to the eye, and to differentiate between materials which to the eye appear similar, as in photomicrography. According to the author, one of the most promising fields of application of infrared materials in engineering lies in the direction of research in the realm of elevated temperatures. Heat rays are visible to infrared materials, but the difficulty at the present time is the great length of exposure necessary when photographing with such rays.

Polarized-light photography makes it possible for photographs to be taken obliquely through water or glass. Similarly, the polaroid material when used as a screen subdues oblique reflections arising from opaque substances having a glossy surface. Oblique reflections from metallic surfaces are not eliminated unless screens are placed between the subject and light and also between the subject and lens. The most promising applications of these screens in engineering work will be found in the elimination of reflections, thus making possible what might otherwise be impossible, the obtaining of greater detail and the power of differentiation.

The principal application of X rays to industry is in the examination of articles during manufacture, to verify either the quality of material or workmanship, to check correctness of assembly, or to analyze failures in service. The atomic weight of the substance examined has a marked effect on the depth of penetration of the rays. Apart from this fact, penetration depends on the voltage applied to the tube. Experience shows that 40,000 volts will penetrate 4 in. of aluminum and 250,000 volts will penetrate 4 in. of steel. Some materials which are now being examined by means of X rays are castings, bombs, fuses, ball bearings, steel plate, boiler drums and tubes, high-pressure piping, and welds.

The gamma radiations of radioactive substances, such as radium, have lately been employed for the same purposes as X rays. By reason of their much shorter wave length, the gamma rays have a much greater penetrative power. The substance usually employed is a salt of radium known as radium bromide. In use, the salt is kept in a thick leaden casket, which is fitted with a removable lead plug. The container is placed a definite distance in front of the specimen to be examined, a photographic plate being placed behind the latter and, with the plug removed, left for an appropriate time. With this technique it is possible to penetrate and examine up to eight inches of steel. Photographs taken in this manner are conspicuous for the lack of scatter of the rays. The process is particularly suitable for use with irregularly shaped and heavy objects.

High-speed photography can be accomplished in one of two ways, namely, by means of a moving optical system or by the use of very bright flashes of light of such extremely short dura-

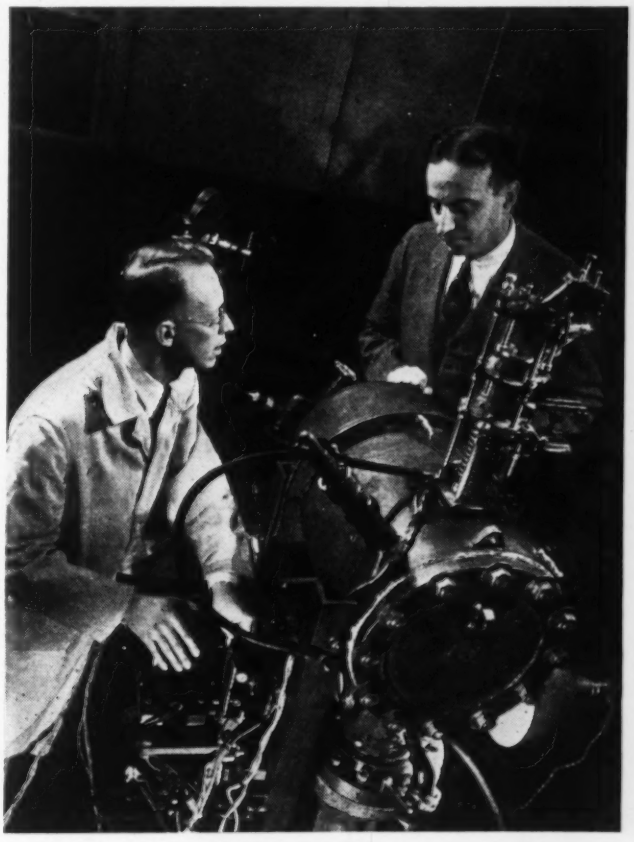


FIG. 5 AN APPARATUS FOR UNDERWATER ARC PHOTOGRAPHY

(In this apparatus built by the Westinghouse Research Laboratories to study circuit-breaker arcs, arcing electrodes are mounted inside a vertical steel cylinder 3 in. in diameter, through which water is pumped upward at velocities as high as 200 fps. On opposite sides of the cylinder are circular windows. For photographing the arc, a miniature camera equipped with supplementary portrait lenses is placed before one window, and the other window is brightly illuminated to make bubbles around the arc appear as silhouettes against a light background. Exposures averaging about 1/3000 sec are made through a slotted disk, which is driven by a small synchronous motor. Contacts on a rotating drum attached to the shutter disk synchronize the camera shutter and record on an oscillogram the exact instant at which the picture is taken.)

tion that no appreciable movement between the image and film is apparent. Because of the complexity of the first method, there is very little commercial utilization of it. The second method has proved its worth in industry. A description of it will not be given here since it was so well covered by R. Merwin Horn in an article that appeared in MECHANICAL ENGINEERING for March, 1938.

Single "stop-motion" photographs have a definite advantage over motion pictures in some cases due to the fact that the pictures are larger and may be studied without projection, because the volume of light per flash is greater, permitting pictures to be taken at from *f* 8 to *f* 22. Probably the greatest sphere of usefulness of this type of camera lies in the solution of industrial problems. The demand for lower costs and higher outputs makes it imperative for designers to have a complete knowledge of what happens to their machines, products, and processes. A few of the successful applications of the apparatus are the study of air flow over airplane sections, recoil action of guns, acceleration curves of electric motors, delay in the action of fuses, the action of high-speed machinery, and circuit breakers (see Fig. 5).

Collision Tests "Zephyr" Train

RAILWAY AGE

TWO of the papers presented at the Semi-Annual Meeting of the A.S.M.E., Denver, Colo., June, 1934, one by E. C. Anderson, member A.S.M.E., and the other by R. Eksergian, fellow A.S.M.E., described the construction of the lightweight, stainless-steel Burlington *Zephyr* train, consisting of three articulated units. A fourth unit was added in 1939. As outlined in the papers, which were published in the September, 1934, Transactions of the A.S.M.E., the use of stainless steel together with a special welding process made it possible to use thin-web structural members, light gussets, and connections, which, with careful technical design, resulted in a structure comparable in strength with present modern steel equipment, but with a reduction in weight in excess of 60 per cent. Another radical departure from conventional railroad design was the absence of a center sill.

One of the questions brought out during the discussion which followed the presentation of the papers was how the train would stand up in a collision. After more than five years of operation, this first *Zephyr* provided the answer when it was involved in a head-end collision with a locomotive and two freight cars on Oct. 2, 1939, at Napier, Mo. According to the I.C.C. Bureau of Safety report, as noted in *Railway Age* for March 2, 1940, the accident was caused, first, by the opening of a junction switch by a trainman without authority or instructions which resulted in diverting the passenger train, the *Pioneer Zephyr*, to an occupied track, and, second, by the failure to control the speed of the passenger train properly when approaching a junction operating against the current of traffic within yard limits. The speed at the moment of impact was variously estimated at less than 45 mph up to 60 mph. The motorman and a roadmaster riding in the cab were killed, five railway mail clerks, eight railway employees, and 25 passengers were injured.

All of the passengers on the train were riding in the two rear cars and escaped without serious injuries, their protection being a notable achievement considering the tremendous forces involved in the collision. The four-car *Zephyr* weighed about 150 tons and the force of impact moved the steam locomotive and two loaded freight cars, weighing a total of 350 tons and standing with the brakes set, a distance said to have been from 90 to 128 ft.

The front end of the *Pioneer Zephyr* power car, containing the Diesel-electric power plant, was crushed, and there was some structural damage to the second car, but practically none to the third and fourth, largely due to the fact that the four car-body units making up this train remained connected at the articulated joints and the train did not turn over or leave the rails. The absence of structural damage or distortion in the two rear cars was shown by the ease of opening doors, following the collision, without evidence of binding, and the fact that only one window was broken.

The report states that the front truck of the power car was derailed and stopped crosswise of the track 10 ft from the pilot of the locomotive; the front end of the first car rested on the front end of the locomotive. The front end of the power unit was demolished a distance of 28 ft; the power plant and its base support were driven back into the mail compartment. The articulation end castings at the rear end of the first car and at both ends of the second car were driven inward 8 to 16 in. and the ends of these two units were bent and damaged.

In making the extensive repairs necessary to the power car, made of stainless steel, the Chicago, Burlington & Quincy R.R. broke new ground and answered many questions which have been raised regarding the possibility of repairing cars which embody this new type of construction, states an article appearing in the same issue of *Railway Age* in which the I.C.C. report on the accident is noted. A very creditable time record was made in rebuilding and repairing the train at the Aurora, Ill., shops where the new front end of the power car was received from Philadelphia in a semiassembled state on Nov. 13, the reconditioned Electro-Motive Diesel engine and generator returned from the builder and applied through the roof on Nov. 14, and the finished train sent out of the shop on Dec. 5.

Referring to Fig. 6, a good idea will be obtained of how the individual cars in this train were damaged. The front end *A* of the power car consists of a Cromansil steel bed which was crushed back a distance of about 6 ft. The engine compartment *B* was largely destroyed and came to rest on the front end of the steam locomotive at an angle of approximately 45 deg. All car-frame members were torn apart at *C*, the engine compartment separating from the rear portion of the car, which contains the railway post office and baggage compartments. The rear end of the car at *D* was damaged by bending the corner posts, end framework, corrugated roof end, and three feet of floor structure. The front end *E* of the second car (baggage) was crushed inward, causing some damage to the end frame, roof, floor members, and front articulation casting. At *F*, the rear of the second car, the corner posts were bent, one collision post broken, and the corrugated roof end displaced. At the forward end of

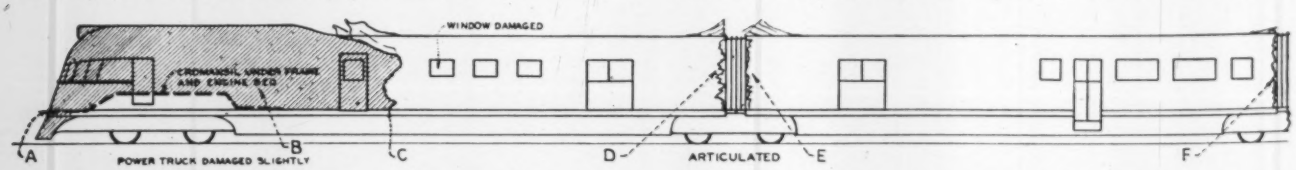


FIG. 6 SIDE VIEW OF FIRST TWO CARS OF *Pioneer Zephyr* SHOWING POINTS AT WHICH DAMAGED IN COLLISION WITH STEAM LOCOMOTIVE AND TWO FREIGHT CARS

the third car (not shown in the illustration), the sheathing was damaged slightly at the right upper corner. The rear observation car had only one broken window, one bent bulkhead partition, and some bent parlor-chair frames.

The principal damage to the Diesel engine was springing the crankshaft, due to tilting of the direct-connected electric generator at the forward end. The front end sill and the bolster center plate of the power truck were broken, along with brake cylinders and other parts. Both axles were bent and the motor housings damaged. Practically the only damage to the second, third, and fourth trucks was breakage of the air-brake cylinders and slack adjusters.

The statement of the damage to the equipment, furnished by the railroad company to the I.C.C., showed a total of $54,000 to the first car, of which $29,000 was to the body and $25,000 to the power plant; to the second car, $5000; and to each of the third and fourth cars, $500—a total of $60,000. The *Pioneer Zephyr* was returned to service on Dec. 6, 1939, and is now being used in daily turn-around service between Kansas City, Mo., and Lincoln, Neb., and has given an excellent account of itself since the repairs were made.

Sickness Absenteeism

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

SICKNESS from ordinary diseases and nonoccupational injuries accounts for the absence of ten per cent of all workers in American industry eight days or longer per year, with an average of slightly more than 39 days for men and 35 days for women. If absences of less than 8 days are included the grand total of days lost is just about doubled. In giving these figures in a talk presented at the winter meeting of the A.I.M.E. in New York, Feb. 12–16, 1940, Dr. C. D. Selby, medical consultant of General Motors, stated that of 8000 absences in his company during the first half of 1939, about 50 per cent resulted from respiratory diseases and 15 per cent from digestive diseases, most of which are preventable. Particular emphasis should be given by industry he said, to cutting down the ordinary disease rate among workers. Up to the present time the emphasis has been entirely upon occupational hazards, which are responsible for only ten per cent of the absenteeism.

One might properly infer from the foregoing that employee output is affected by absenteeism and the factors that contribute or enter into it. This may be sufficient in itself to arouse industry's concern. However, here is another aspect, the scope of compensation is being gradually extended to include payments for disabilities resulting from certain borderline diseases which might be indirectly the result of employment or aggravated by it. In this, the possibilities for increased costs are legion. As to what industry can do about it, Dr. Selby suggested for its consideration the following program:

1 Applicants for employment: (*a*) pre-employment examinations; (*b*) safe placement; and (*c*) probationary period.

2 Established employees: (*a*) sickness records; (*b*) control of harmful working environments; (*c*) periodic health examinations; (*d*) temporary relief for minor ailments; (*e*) first aid in urgent sickness; (*f*) rehabilitation; (*g*) health advice; (*i*) cooperation with official health agencies; and (*j*) cooperation with the workmen.

In elaborating upon the last subject, he claimed that no health-maintenance program can be a substitute for the employees' own efforts to preserve their health, which after all is their own very personal concern depending upon their day-to-day living, their rest, recreation, food, and exercise, especially since only about 25 per cent of their time is spent in the plant.

Steps in Job Control

METROPOLITAN SECTION, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

JOB control is a very important function of today's management since it involves many steps which are interdependent upon each other, states Charles W. Lytle, member A.S.M.E. and professor of industrial engineering at New York University, in a paper he presented at a meeting on Nov. 27, 1939, sponsored by the time and motion group of the Metropolitan Section, The American Society of Mechanical Engineers. This interdependence is particularly important when the subject of job evaluation is considered. An analysis of the several plans of job evaluation in use today was covered by J. E. Walters, member A.S.M.E., and A. W. Bass, Jr., in two papers published in the December, 1938, issue of MECHANICAL ENGINEERING.

Professor Lytle goes a little further in his paper by including a summary of the steps leading up to and from job evaluation. These steps, aside from the service controls which plan, dispatch, inspect, and cost, number six and make possible the creation and control of groups of jobs.

The steps are:

1 Invention and construction, which include the development, design, and production of equipment, jigs, tools, and auxiliaries.

2 Job standardization, which consists of the development and standardization of the most expedient arrangements, motions, and times for producing goods or services.

3 Job review, which includes a systematic analysis, specifications, and classifications of job characteristics in relation to minimum qualifications of employees.

4 Job evaluation, that includes a determination of the relative importance of job characteristics to establish base rates.

5 Merit rating, which is a determination of relative employee merit that must be compensated through time rates. (Where there is an extra-financial incentive applied, this step may be eliminated as each employee demonstrates his own rating, and pay variation per hour is automatic and impersonal.)

6 Incentives, plus both nonfinancial and extra-financial incentives to incite optimum employee response and to reward the same according to advance arrangements.

Step 1 is obviously a function of an engineer, usually mechanical; the next step, without exception, is a function of the industrial engineer; and step 3, although inspired by the work of Taylor and Hathaway, has been developed by the personnel people, who are being aided now by the industrial engineer in an increasing degree. Step 4 originally was a line function, but as it broadened, the employment department began to furnish surveys and, in time, to carry out the necessary investigations. At present, all collected information passes to a representative "wage committee" which sifts it, perhaps synthesizes from it, and makes recommendations which are rejected or authorized by a line executive. In large companies, besides the general committee, there may be several local committees. Membership on these committees varies, but usually the general committee includes both a personnel man and an industrial engineer.

Step 5 is usually performed by the personnel department in its follow-up of employees. The last step might logically be a personnel function also were it not for the fact that historically practically all incentives were designed and applied by industrial engineers. However, it is wise to have the personnel people included for all important incentive problems so that the human side may not be overlooked. The sequential nature of the steps suggests the necessity for cooperation between engineers and personnel staffs.

LETTERS AND COMMENT

Brief Articles of Current Interest, Discussion of Papers in Previous Issues

Unionization of Engineers[1]

To the Editor:

Mr. Herron's paper, "Unionization of Engineers," raises the question: "Shall or shall not engineers affiliate with existing labor unions?" My answer is emphatically, "No"—if the practice of engineering is to rank as a profession and not as a trade. As I see it the ethics, obligations, and moral standards of any "profession" are not compatible with the practices of labor unions as such are conducted today. The weapon of the labor union is the strike. If I remember rightly, quite a while ago in some strike which created national interest, a labor leader was quoted as saying that violence was the final resort in forcing acquiescence to a union's demands, and it seems to me that this is a reasonable viewpoint. It is hard to picture a successful pacifist strike. Thus if engineers are to join unions they must be prepared to accept the practices and do as the labor unions do. I cannot conceive of a body of engineers engaging in a sit-down strike; shutting down a vast power system; walking off and leaving a municipal water supply; or acts that cause inconvenience, suffering, and loss to innocent third parties; and by reason of clamor, punishment, and inconvenience, force recognition of demands, reasonable or otherwise.

As I view it, engineering is a profession, not a trade. Its disciples are obligated to develop a better and a happier world by the use of such talents as they possess in the fields of science and invention and not through brute force and selfishness.

Unquestionably, the laborer is worthy of his hire. Unquestionable, also, is the fact that the engineering profession as a whole has not received the financial recognition due its achievements. But two wrongs do not make a right and it is better, in my judgment, for the engineering profession to fail to receive its just recompense rather than lower its moral and ethical standing.

It seems to me that engineers have been overlooked rather than discriminated against, and are due the same consideration as that accorded other vocations. Men who devote four years to obtaining technical education deserve just compensation and are entitled to some degree of security in their positions. Unfortunately, in the past an engineer's job has too often been treated as "casual labor" and his insecurity worked hardships and injustice on himself and his dependents. The same insecurity, of course, has applied to labor, and labor has organized.

As Mr. Herron points out, the union movement has come about as a result of corporate industrial organization. The impersonal character of the corporation has swept aside the personal relation between employer and employee. If our capitalistic system is to continue, labor organization must also continue and increase. Like any new movement, labor organization has dealt in excesses and the pendulum has swung too far to the left. I trust and believe that time will right this condition and the future will develop a balanced, stable, and equitable status between capital and labor.

In lieu of any affiliation with labor unions, it seems to me that an organization of engineers could be effected through the national societies. Until recent years the great technical societies have held aloof from any consideration of the social status of the engineer. An examination of the records and transactions of the societies reveals a wealth of technical knowledge but a dearth of any consideration of how, when, and where the engineer's bread and meat are to come from.

That men of standing, such as Mr. Herron and others, are giving thought to the social status of engineers and writing articles on the subject in both technical and nontechnical press is the most hopeful sign that the profession is awakening to its responsibilities.

As a closing thought, as I see it, the engineers must decide whether they shall become regimented with all of the drawbacks and disadvantages of regimentation, or whether they shall continue as free agents, nevertheless coordinated and acting as a unit in matters that affect both the individual and society.

Chas. E. Waddell.[2]

To the Editor:

My attention has been called to the article in the November, 1939, issue of your publication by James H. Herron entitled "Unionization of Engineers," and I have been invited to write you my reaction to this article. I am glad to do so as follows:

First, I would like to say that I think Mr. Herron has rendered a real service to the engineering profession and particularly to the younger members thereof in writing as he did. His article is most thought-provoking.

My experience both in dealing with younger men in my own business and in trying to bring up my four sons in the way in which they should go leads me to believe that while Mr. Herron is absolutely sound in stating that the engineer should think of service as his principal concern and pointing out that the engineer's salary depends upon the services he renders—service first then salary—it is most difficult to make young men believe that the job seeks the man. Logically, the amount of salary must depend upon the amount of service rendered. Promotion and success follow service and are absolutely dependent upon it. Men at the top in any profession or in business are always seeking young men upon whom additional responsibility can be placed and to whom they are glad to pay larger salaries if they can earn them. These principles are immutable and no organization, union or otherwise, can in general or for the long pull modify this fundamental.

The real question is how to make the young man believe these facts, particularly in the face of his knowledge of the benefits which unionization, so far as monetary compensation goes, has given to so many hundreds of thousands of employees the country over. Perhaps if they could appreciate that there is no true analogy between what bricklayers, automobile workers, or textile workers can do for themselves through unionization

[1] A third group of letters commenting on an article "Unionization of Engineers," by James H. Herron, Mechanical Engineering, vol. 61, November, 1939, pp. 788–789 and 822.

[2] Asheville, N. C. Mem. A.S.M.E.

and the situation with respect to professional engineers, they would look at this question differently.

As Mr. Herron so well points out, unionization is in many ways the antithesis of professional ideals and ethics. To me they are as much the opposite ends of the stick as the term "professional sport" has always seemed. You can't be a professional and be a sportsman. You can't conform to union principles and at the same time live up to the ideals and precedents of the engineering profession.

The recent activities of one or two organizations attempting to unionize the younger groups of the engineering profession are in actuality nothing new. Some twenty years ago the American Association of Engineers staged a nation-wide campaign to raise young engineers' salaries. While they didn't call themselves a union, their goal was the same as that of the present-day agitators.

The past is a pretty good guide to the future. What happened to the A.A.E.? They went up like a skyrocket and came down like a stick. In a very few years their membership grew to 20,000. Today, I would have difficulty in locating their office and I doubt if they have more than 1500 members. Why did this drive for collective bargaining in the ranks of the engineering profession fail? Didn't it founder on the rocks of objectives impossible of attaining and maintaining in a profession?

Are there any unions amongst lawyers, doctors, dentists, or architects?

Can the young men serve two masters? Can they be faithful to the ideals of the engineering profession and be slaves to union delegates or put their own immediate monetary welfare ahead of their life's goal?

Youth should remember that the race of life is not a sprint won in the first ten seconds. It is a cross-country run where the sprint comes at the end of the contest.

While I believe all the foregoing to be uncontradictable, I realize it is difficult to sell preachments to youth, particularly in this day when even the law of supply and demand is questioned by modern crackbrained economists and that some answer which will appeal to youth should be found by those managing the great engineering societies of the country. Increased activity along welfare lines by the Founder Societies is probably desirable.

Perhaps if youth realized how unions break the scale in tough times and have to bow to the law of supply and demand they would appreciate that even the strongest union of subprofessional engineers, draftsmen, and technicians can't get blood out of a stone and that in general wages paid in the drafting rooms and the field forces of the engineering world are market-wise, fair, and all that traffic will bear.

Most experienced men know the futility of membership drives, whether for a Y.M.C.A., chamber of commerce, or country club. High-pressure salesmen can double the membership of almost any organization. The real test, however, is: Will such membership continue? Most sound organizations grow slowly and membership that sticks flows to the institution on a basis of need or merit. I believe any high-pressure selling of unionization amongst engineers withers in the fierce sun of facts.

Grant that unionization may temporarily raise wages—it does so at a grievous cost in that it levels men and leveling is the obverse of leavening; and leavening of the spirit of service is what youth in the engineering profession needs above all else.

J. P. H. PERRY.[3]

TO THE EDITOR:

I agree with Mr. Herron's statement, "Engineers and labor unions, in my opinion, have so little in common that unionization of engineers is at least an unnatural development."

The New York Society of Professional Engineers made a press release on Jan. 18, 1939, condemning the professional-engineers' union as follows:

> The N. Y. State Society of Professional Engineers, through Alfred E. Roche, its President, announced last night from its Albany headquarters that the recent formation of a "Supervising Professional Engineers Union" is diametrically opposed to the fundamental concepts of the Society. Both the State Society and the National Society of Professional Engineers have previously gone on record as fundamentally opposed to any idea of the unionization of professional men.
>
> "Engineers and other professional men," President Roche declared, "do not belong in labor unions and should not be solicited nor encouraged to join. Unionization is inconsistent with the professional spirit and attitude, which places the highest service to the public above personal gain. The State Societies of Professional Engineers and their National Society are interested in improving the economic and professional status of engineers, but believe this should be accomplished through education and public appreciation and not through the methods of unionization. We recognize that unionization has its place, but that place is not in the learned professions. Professional men occupy a position of public trust, between capital and labor, and unionization is inconsistent with the highest discharge of that trust. We advise professional engineers not to affiliate with any union."

[3] New York, N. Y. Mem. Am.Soc.C.E.

I am not a member of the New York Society of Professional Engineers but I think that they have stated the matter very well in the press release quoted.

In my opinion the only way in which an engineer can make progress in his profession is to do something to *earn* the progress. Dr. Harold G. Moulton of the Brookings Institution has been pointing out for years that the only road to prosperity is by technological improvements resulting in lower prices which distribute the benefits to the whole public. Whenever groups have not tried to skim the cream for themselves by using technological advances to greatly increase profits to capital or higher wages for labor but have lowered prices, they have not only benefited themselves but the public as well.

Professional men usually lose whenever there is inflation. Engineers ought to know better than to try to form a pressure group to artificially raise their compensation.

It will be much more effective in the long run to direct the efforts of the profession toward making the profession really more worth-while so that its contribution will be greater, and trust that the remuneration will be a by-product. We must all come to recognize the philosophical principle that many things which some people want most cannot be obtained on a permanent basis by direct approach.

It has long been recognized that happiness is a by-product. President Dodds[4] of Princeton has pointed out that security is a by-product. I believe that remuneration has got to be a by-product. The condition of the building trades is a sample of what happens when a group forces a rate of pay which for lack of technological advancement they are unable to earn. In other words, when people do not earn their rate of pay the public cannot afford to hire them.

A. R. STEVENSON, JR.[5]

TO THE EDITOR:

You should form a committee at once to set up a Junior grade of engineering covering engineering work of routine nature and low skill and then form a Junior Craft Union, to cover this grade of work, and the committee should also determine the rates of pay.

The same committee should determine a work of professional grade, work of such type as to vitally affect the safety of the public, or require men of professional

[4] "The Perils of Security," Official Register of Princeton University, June, 1937, vol. 28, no. 11.

[5] Schenectady, N. Y. Mem. A.S.M.E.

type and executive grade and institute legislation to protect this grade.

This work must be carefully done because you cannot legislate anyone to prosperity or fame and you never can maintain an artificially high wage to the benefit of anyone.

K. J. DICKERSON.[6]

TO THE EDITOR:

Mr. Herron's views on unionization of engineers stimulate interest. In certain localities and manufacturing plants it is reported that extreme pressure is brought to bear on the younger engineers to join unions. They are men of recent graduation who enter a period of training or apprenticeship in shops. The character of their work is perhaps largely associated with production. They exert little effort which may be classed as engineering. Employment may consist of simple testing, or clerical aid to superintendents or production or construction engineers, timekeeping, and the like. During such occupation the young engineer has an opportunity to observe processes and methods and gain basic experience.

This question is pertinent: "What is the source of, and reason for, efforts to unionize these employees?" It has been generally observed that little if any initiative is with the individual engineer. In fact he is characteristically resistant to this pressure, preferring to paddle his own canoe and take chances of progress in accordance with ability. Rarely would an employer advocate unionization of engineers. Employers might desire younger men, who may later be given responsibility over construction or production groups, to know intimately the reactions and opinions of large groups of skilled and unskilled workers. This knowledge might be gained through union affiliation.

If the younger men could gradually obtain influence in such groups and develop critical judgment of proposed action, their membership and expressed views might be desirable. This is, however, unlikely of accomplishment, because in most unions the majority vote follows the noisy forceful argument in preference to quiet reason. Unfortunately, the political leadership in most locals is of the former type. The young engineer's reasoning would receive little attention. It must be admitted, however, that his development would advance through better understanding of workmen's aims and observation of the methods of influencing them as individuals or in groups.

[6] Swampscott, Mass. Jun. A.S.M.E.

We may therefore dismiss either the individual engineer or the employer from the charge of initiating the movement. This leaves only the existing union organizations, their leaders, and members. Their motives are, doubtless, not actually concerned with securing advantages for the young graduate who is sometimes looked on with distrust as a probable future boss and especially lucky fellow who will progress faster because of his education. Rather, the union leaders see an opportunity of adding to the strength of their positions by acquisition of members, dues, majority of employees, and perhaps greater control of factory production as the engineer's responsibility increases. If the engineer is not a union member his loyalty in case of an argument will doubtless go to the management. His future progress as he sees it will be in proportion to his share of management responsibility. So unless he may be controlled as a member, he will be a potential strikebreaker or at least an aid to management. (Having acted as a substation operator during a strike I know the feeling.)

Another pertinent question for which the young graduate must seek answer is: "What will be the direct benefit to me?" *Wages?* More liable to occur for the potentially able boy would be a leveling off to the average of a large group, than individual recognition and reward. In fact the average return to any union group he may join may include lower-paid classes of workers and may further reduce his ceiling while he is a member. *Preferment?* Submersion of individual worth is more likely to occur. *Shorter hours?* Most ambitious boys enjoy their work, and their personal development within reason is proportionate to longer hours of work. *Recognition of the profession?* Certainly this should be obtainable by other means. Recently published figures indicate recognition exists in that engineers top the list of professions in return during the depression. Unionization, if sought by engineers would act as a discredit rather than as an aid to recognition.

Concluding, I have observed that where free choice has been offered by employers without prejudice to standing, the young engineer's common sense has impelled him to doubt the benefit of joining a union.

AN A.I.E.E. MEMBER.

TO THE EDITOR:

Mr. Herron's article on the unionization of engineers should stimulate much thought among young engineers.

Frankly, my own start in engineering was very idealistic. I made up my mind in high school to achieve success in some field of engineering where I could exercise my creative impulses. I changed my mind in college and prepared myself for work in public service. At present this is in industrial engineering.

I believe in Mr. Herron's code of conduct implicitly, but at the same time do not believe that the engineer and labor (unions) are too divergent in their views. Labor is becoming younger and more intelligent with each succeeding generation. More and higher ambitions have to be satisfied as a result. At the same time labor is becoming more "sales- and consumer-conscious" *when handled in the right manner.*

It seems to be the general opinion that only those who are graduated from an institution of higher learning are professionals, and that only these work under a code.

While the worst of union activities and demands have been made public, how many of the best efforts of labor have received the same publicity? I think if the average worker were questioned we would find just as high a code of ethics there as in our "profession."

The fact of the matter is that I attended college only after careful consideration of my chances for obtaining high position with or without the theoretical knowledge gained in school. In other words, my success was to be measured in terms of position and money. I felt that monetary consideration should come first up to the point of having a comfortable living; and that if this was assured I could then devote my time to purely professional development with money a secondary consideration.

A little logical thought will bring out the fact that security and a comfortable living are foremost in every man's mind, whether he is a "professional," laborer, or manager. After the family, comes the general public, the nation, or our fellow man. Obviously, the majority of the people in the United States have not passed this point of comfort and a union is one logical means of approach when industry or government fails to provide it.

Some of the prominent older engineers seem to have forgotten they were Juniors when they express doubt that money should come before "nonfinancial" rewards. Praise may satisfy one's ego, but rarely one's stomach. Titles may sound good, but hardly put additional dollars in the pocket to pay the insurance. It is a good thing to serve an apprenticeship, but not so good when one is left on a routine job for months with no chance to exercise a mind trained

to analyze real problems. It is very encouraging to listen to high-sounding talk by industrial leaders, and very discouraging to find your way blocked by relatives of these same executives.

The old idea of sharing the profits comes in for its share of the discussion. How many engineers have saved firms thousands of dollars by methods changes and received no share in the savings? Executives receive bonuses—why not engineers?

It is doubtful if employers pay their engineers commensurate with their responsibility and the decisions they must make—at best a few are attempting salary evaluation.

I heartily approve of the idea of a union among engineers if it can be worked out in conjunction with the A.S.M.E. and similar societies; and with the assurance that discrimination will not take place between employer and employee. Mr. A. A. Bato[7] seems to have a plan of action to start the ball rolling.

K. M. LOUGHMILLER.[8]

TO THE EDITOR:

Mr. Herron presents the question: "Should the engineer join a labor union?" If that is the only way the engineer can secure his full share of the national income, he has no choice. The moment he receives his union card, however, he is disqualified to perform one function of the engineer. That is to increase the quantity, improve the quality, and lower the cost of production.

The labor union places wage increases and shorter hours above all else. The actual net gain to labor, after all costs of winning objectives have been deducted, is not always as great as is generally supposed.

Tables in "The National Income and Its Purchasing Power," by Willford I. King, show that the average annual earnings of wage earners in the manufacturing industries were $544 in 1909 and $1140 in 1928. In twenty years average annual earnings in dollars more than doubled. When the buying power of these earnings is arrived at by correcting them to the buying power of 1913 dollars, the table shows $526 for 1909 and $668 for 1928, or an increase in actual buying power of only about 25 per cent.

When we turn to the table showing the percentage of the national income obtained by the various groups we discover the wage earners got 35.56 per cent in 1909 and 36.05 per cent in 1928. Salaries went from 14.58 per cent of the national income in 1909 to 19.93 per cent in 1928. Most of this increase, however, was due to the fact that business organization became larger and larger and more and more of those who would have been in business for themselves in 1909 were drawing salaries in 1928.

Apparently, labor unions have not been able to increase the percentage of the national income which goes to labor to any marked degree and maintain the gain. Labor did succeed in getting 38.6 per cent of the national income in 1923, but salaries started up and lowered that percentage in the years which followed. In other words, in spite of the fact that salary earners have not been as well organized as have wage earners, salaries have held their own. The law of supply and demand appears to have done its work.

Because there is grave doubt that the engineer would increase his buying power by joining a labor union and because the policies of some unions prove costly to their members, as well as the fact that labor-union membership may prove a decided handicap in winning advancement, each engineer, who considers such membership, needs to weigh the advantages and disadvantages with the greatest care before he takes the step. Sooner or later, if we are to achieve the highest possible degree of prosperity, remove labor relations from politics, and give each person the utmost in buying power, there must be research which will indicate to a high degree of accuracy the division of the sales dollars which will result in the greatest permanent advantage to everybody.

This research will cover the entire field. It will show how many cents out of the dollar should go to wages, salaries, investors, raw material, and elsewhere. This research is an engineering job. Though national organizations of management, finance, and labor would probably be represented on the committee, the actual work would fall largely to the engineer. If he is not tied up too closely to labor unions, he can do this job better.

J. E. BULLARD.[9]

[7] See MECHANICAL ENGINEERING, January, 1940, pp. 69–72.

[8] College Station, Texas.

[9] Central Valley, N. Y. Assoc. A.S.M.E.

A New Market—An Appeal

TO THE EDITOR:

The Chinese people will someday become an important market for America's manufactured products. Just now this market needs to be developed through contributions of American manufacturers.

The situation is briefly this: Between fifty and sixty million Chinese have been driven to the interior of China and are forced to reconstruct their industries which have been destroyed through war. They are endeavoring to do this through the establishment of small production centers producing every conceivable type and variety of product to meet the essential needs of daily living.

Fifteen hundred of such small individual shops have been established and it is planned to set up at least thirty thousand. Coincident with the establishing of these shops the Chinese are setting up central laboratories for the purposes of:

1 Improving manufacturing methods of the existing production units.

2 Assaying raw materials for them and standardize finished products.

3 Making surveys of local available raw materials.

4 Developing processing and refining methods for these materials.

5 Working out manufacturing methods for urgently needed drugs no longer obtainable through import.

6 Training field assistants and technical inspectors.

One such laboratory is established in the northwest of China. A second one is now being set up in the southeast. The head of this laboratory is Dr. Eric Landauer, a chemist formerly on the staff of the League of Nations. He and his assistants are volunteering their services and are subsisting on the barest living allowance. They need equipment. The most urgently required are the following:

(*a*) A kerosene-oil 10-hp engine, with belt-driven 100-volt direct-current generator, and switchboard, wiring, and accessories.

(*b*) Shafting and accessories for power distribution to needed ball mill, pumps, blower, compressor, lathe, filter press, and acid eggs.

(*c*) A quantity of miscellaneous chemical-laboratory instruments and equipment.

Any manufacturers who would care to donate any of this equipment should communicate with the undersigned, who will supply them with a detailed list of the needed equipment and with shipping instructions.

WALTER RAUTENSTRAUCH.[10]

[10] Professor of Industrial Engineering, Columbia University, New York, N. Y. Mem. A.S.M.E.

A.S.M.E. BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and also published in MECHANICAL ENGINEERING.

Following is a record of the interpretation of this Committee formulated at the meeting of January 19, 1940, which was subsequently approved by the Council of The American Society of Mechanical Engineers.

CASE No. 888

(Interpretation of Par. P-112)

Inquiry: Socket-type welded connections to valves, boiler trimmings, and fittings are not provided for under Par. P-112. Such construction consists of inserting a pipe into a machined socket and fillet welding it to the hub thereof. May this type of joint be used?

Reply: The type of socket joint described may be used provided the nominal pipe size does not exceed 4 in.; the depth of the socket is not less than $^1/_4$ in.; the end of the pipe before welding is not less than $^1/_{16}$ in. from the bottom of the socket; the throat dimension of the fillet weld is not less than the thickness of the pipe wall; the hub thickness is not less than $1^1/_4$ times the nominal pipe thickness; the weld is not in contact with the furnace gases; the qualification of the welding procedure and the welding operator complies with Pars. A-100 to A-120, inclusive, for a butt joint with parts to be joined in a horizontal-fixed position; and the other requirements of Par. P-112 are met.

CASE No. 889

(Interpretation of Par. P-112c)

Inquiry: Par. P-112*c* specifies that backing rings shall be used for pipe or tube connections where the outside diameter exceeds $1^1/_2$ in. Was it the intent to require backing rings on pipe with an inside nominal diameter of 1 in. and an outside diameter of 1.9 in.?

Reply: As a result of reconsidering the requirements of Par. P-112*c* as applying to small pipes or tubes, it is the opinion of the Committee that backing rings shall be used for all pipe or tube single-welded butt joints welded under the requirements of Par. P-112, where the outside diameter exceeds $2^1/_2$ in. for carbon steel material, and $1^1/_2$ in. for all alloy pipe or tubes.

CASE No. 890

(Interpretation of Par. P-102i)

Inquiry: Is it necessary in a locomotive-type boiler of welded construction to radiograph all circumferential, or roundabout butt-welded joints in the outer shell even though the principal longitudinal stresses thereon are supported by staybolts and bracing?

Reply: It is the intent of Par. P-102*i* of the Code that all of the butt-welded seams in the external shell referred to must be radiographed.

CASE No. 891

(Special Ruling)

This case was formulated at a meeting of the Executive Committee of the Boiler Code Committee on January 30, 1940, and approved by the Boiler Code Committee.

Inquiry: Par. P-101 which provides for the welded fabrication of cylindrical pressure parts of boilers, covers the construction of superheater headers. Is it permissible to fabricate superheater headers when formed of pipe not exceeding 16-in. nominal pipe size, under the requirements of Par P-112?

Reply: Proposed revisions of Pars. P-101 and P-112 were published in the December, 1939, issue of Mechanical Engineering. Inasmuch as no criticism thereof has been received, it is the opinion of the Committee that superheater headers not exceeding 16-in. pipe size or $1^5/_8$ in. wall thickness, which are not in contact with furnace gases, may be constructed under the requirements of Par. P-112. This does not apply, however, to waterwall headers.

Revisions and Addenda to Boiler Construction Code

IT IS the policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the rules and its codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the code, to be included later in the proper place in the code.

The following proposed revisions have been approved for publication as proposed addenda to the code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the code, and are submitted for criticism and approval from anyone interested therein. It is to be noted that a proposed revision of the code should not be considered final until formally adopted by the Council of the Society and issued as pink-colored addenda sheets. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communications should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

PARS. P-1*b*, L-1*b*, H-5*b*, M-2 second section, U-12*b*. Revise to read:

b If, in the development of the art of boiler (pressure-vessel) construction, IT IS DESIRED TO USE materials other than those herein described [become available], DATA SHOULD [specifications may] be submitted TO THE BOILER CODE COMMITTEE IN ACCORDANCE WITH THAT SHOWN IN PARS. X-1 TO X-11 IN THE APPENDIX [for consideration].

PARS. X-1 to X-11. These paragraphs will consist of the text headed Approval of New Materials Under the A.S.M.E. Boiler Construction Code which appeared in the May, 1938, issue of MECHANICAL ENGINEERING, including editorial corrections.

PARS. P-102 and U-68. Revise (*a*) to read:

a Test Plates. A TEST PLATE [two sets of test plates] of the dimensions shown in Fig. P-2 from steel of the same specifications and thickness as the shell plates prepared for welding, may be attached to the shell plate being welded, as in Fig. P-1 [one set], on ONE [each] end of one longitudinal joint of each drum

so that the edges to be welded in the test plate[s] are a continuation of and duplication of the corresponding edges of the longitudinal joint. In this case the weld metal shall be deposited in the test plates continuously with the weld metal deposited in the longitudinal joint. The plates for test samples may be taken from any part of one or more plates of the same lot of material that is used in the fabrication of welded vessels and without reference to the direction of the mill rolling. As an alternate method, A detached test plate[s] may be welded as provided for in (*b*).

Revise (*b*) to read:

b When A test plate[s] IS [are] welded for the longitudinal joints, none need be furnished for circumferential joints in the same drum, providing the welding process, procedure, and technique are the same. Where a drum has only circumferential joints, [two sets of] A test plate[s] of the same material as the shell shall be welded in the same way as the joints in question.

When noncylindrical pressure parts are not integral with the drum or shell, A [the two] test plate[s], of a thickness not less than that of the parts, shall be provided.

When there are several pressure parts being welded in succession on any one order, the plate thicknesses of which fall within a range of $^1/_4$ in., with diameters differing not more than 6 in., and of the same grade of material, A [two] test plate[s] shall be furnished for each 50 linear feet, or fraction thereof, of THE MAIN welded joints.

Revise (*d*) to read:

d Test Specimens. [The inspector shall select one of the two welded test plates, from which] The coupons for tension and bend test [and for specific gravity determinations] shall be removed as shown in Fig. P-2 and be of the dimensions shown in Figs. P-2 and P-3.

Revise (*e*) by replacing the parenthetical expression at the end of the second section by the following:

(The tension test of the joint specimen as specified herein is intended as a test of the welded joint and not of the plate. IF THE SPECIMEN BREAKS IN THE PLATE AND THE WELD SHOWS NO SIGN OF WEAKNESS, THE TEST MAY BE ACCEPTED AS MEETING THE REQUIREMENTS EVEN THOUGH THE STRESS AT WHICH FAILURE OCCURS IS LESS THAN THE MINIMUM OF THE SPECIFIED RANGE.)

Delete (*g*).

Revise (*h*) to read:

h Retests. Should any of the tests [other than the specific gravity tests] fail to meet the requirements by more than 10 per cent, no retests shall be allowed.

Should any of the tests [other than the specific gravity tests] fail to meet the requirements by 10 per cent or less, retests shall be allowed [on specimens cut from the second test plate]. A SECOND TEST PLATE SHALL BE WELDED BY THE SAME OPERATOR WHO WELDED THE PLATE WHICH FAILED TO MEET THE TEST REQUIREMENTS. THE RETEST SHALL BE MADE ON SPECIMENS CUT FROM THE SECOND PLATE.

The retests shall comply with the requirements. For either of the tension retests, two specimens shall be cut from the second test plate, and both of these shall meet the requirements.

When there is more than one specimen of the same type and when one or more of the group specimens fail to meet the requirements by 10 per cent or less, the retest shall be made on an entire group of specimens, which shall meet the requirements.

[Should the specific gravity obtained on the specific gravity specimens be less than 7.75, no retest shall be allowed. Should the specific gravity lie between 7.75 and 7.80, a retest shall be allowed. The retest shall show a specific gravity of not less than 7.80.]

(Last paragraph remains unchanged.)

Revise first section of (*i*) to read:

All longitudinal and circumferential welded joints of the structure shall be examined throughout their entire length by the X ray or the gamma ray method of radiography. [In case the wall thickness exceeds $5^1/_4$ in., and until such a time as evidence is submitted to the Boiler Code Committee that greater thicknesses can be commercially examined, the joints shall be stress relieved and then radiographed when the thickness of the metal deposited in the weld is $5^1/_4$ in. The joints shall also be stress relieved after the completion of the welded-joint.]

FIG. P-1. Revise upper figure to show a test plate on one end of drum shell.

FIG. P-2. Revise figure to delete specific-gravity specimens and reduce width of plate by amount required for these specimens.

FIG. P-3. Revise figure to delete specific-gravity specimens.

Revise *i* (1*a*) to read:

(1*a*) To determine whether the radiographic technique employed is detecting defects of a thickness equal to and greater than 2 per cent of the thickness of the base material, thickness gages or penetrameters of the following type shall be placed on the side of the plate nearest the source of radiation and used as directed.

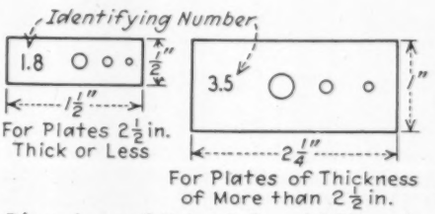

Identifying Number
1.8
1/2"
1 1/2"
For Plates 2 1/2 in. Thick or Less
3.5
1"
2 1/4"
For Plates of Thickness of More than 2 1/2 in.
Diameters of Holes 2, 3, and 4 Times the Thickness of Pentrameter but Not Less than 1/16 inch

FIG. P-4 DIMENSIONS OF PENETRAMETERS

The material of the penetrameter shall be substantially the same as that of the plate under examination.

The thickness of the penetrameter shall be not more than 2 per cent of the thickness of the plate.

There shall be three holes in each penetrameter of diameters equal respectively to two, three, and four times the penetrameter thickness, but in no case less than $^1/_{16}$ in. The smallest hole must be distinguishable on the radiograph.

Each penetrameter shall carry an identifying number representing, to two significant figures, the minimum thickness of plate for which it may be used.

The images of these identifying numbers shall appear clearly on the radiograph.

For plates up to and including $2^1/_2$ in. in thickness, each penetrameter shall be $1^1/_2$ in. long and $^1/_2$ in. wide. For plates thicker than $2^1/_2$ in., each penetrameter shall be $2^1/_4$ in. long and 1 in. wide, as shown in Fig. P-4.

Two penetrameters shall be used for each exposure, one at each end of the exposed length, parallel and adjacent to the weld seam with the small holes at the outer ends.

PAR. P-104*e*. Revise to read:

e The design of welded drums or shells shall be such that bending stresses are not brought directly upon the welded joint. NO SINGLE-WELDED BUTT JOINT OR FILLET WELD SHALL BE USED WHERE A CONCENTRATED BENDING STRESS WILL OCCUR AT THE ROOT OF THE WELD DUE TO BENDING OF THE PARTS JOINED, AS IN THE CORNER WELD SHOWN IN FIG. P-4$^1/_2$, UNLESS THE PARTS ARE PROPERLY SUPPORTED INDEPENDENTLY OF THE WELDS. [Corner welds shall be avoided unless the plates forming the corner are properly supported independently of such welds.]

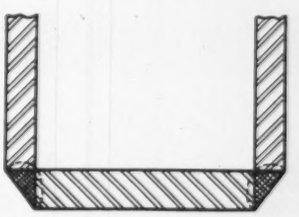


FIG. P-4$^1/_2$ EXAMPLE OF CORNER WELD SUBJECT TO BENDING STRESS

PAR. P-112*a*. Insert the following as (5):

(5) Socket-type joint connections of pipes to valves or fittings may be used provided the nominal pipe size does not exceed 4 in.; the depth of the socket is not less than $^1/_4$ in.; the end of the pipe before welding is not less than $^1/_{16}$ in. from the bottom of the socket; the throat dimension of the fillet weld is not less than the thickness of the pipe wall; the hub thickness is not less than $1^1/_4$ times the nominal pipe thickness; and the weld is not in contact with the furnace gases.

PAR. P-112*c*. Revise first sentence of third section to read:

Backing rings shall be used for all pipe or tube single [V] welded BUTT joints, WELDED UNDER THE REQUIREMENTS OF THIS PARAGRAPH, where the outside diameter exceeds $2^1/_2$ IN. FOR CARBON STEEL MATERIAL, AND $1^1/_2$ in. FOR ALL ALLOY PIPE OR TUBES.

Revise first sentence of fourth section to read: CARBON STEEL PIPE OR TUBE JOINTS UP TO AND

INCLUDING 1/4 IN. NOMINAL THICKNESS NEED NOT BE STRESS RELIEVED. CARBON STEEL PIPE OR TUBES OVER 1/4 IN. NOMINAL THICKNESS AND ALLOY PIPE OR TUBES OF ANY THICKNESS [All pipe or tube joints welded under the provisions of this paragraph] shall be stress relieved in accordance with Par. P-108, after welding and shall be hydrostatically tested in accordance with Par. P-329.

FIG. P-5 1/2(*c*). Change width from 5/16 in. to 3/8 in., and thickness from 5/64 in. to 3/32 in.

PAR. P-186*d*. In (1) and (2) change carbon limit from "0.30" to "0.35" per cent.

PAR. P-216. Revise second sentence to read:

Any part of the tube sheet which comes between the tube, or cylindrical furnace and the shell, need not be stayed if the greatest distance measured along a radial line from the inner surface of the shell to the center point of the tangent to any two tube holes or tube hole and cylindrical furnace on the shell side of such holes, does not exceed 1.5 times the VALUE "P" OBTAINED BY APPLYING THE FORMULA OF PAR. P-199 WITH "C" EQUAL TO 112 OR 120 DEPENDING UPON THE PLATE THICKNESS [maximum pitch of staybolts for the corresponding plate thickness and pressure given in Table P-10].

PAR. P-251. Add the words "except as provided in Par. P-113" to the first sentence; revise last sentence to read:

The [closed] ends of stub tubes MAY BE CLOSED BY EITHER [shall be welded by the] forge OR FUSION WELDING [process]. FIG. P-26*f* AND *i* ARE SOME OF THE ACCEPTABLE FORMS OF CLOSURE WHEN NOT EXPOSED TO GASES OF COMBUSTION AND WHICH NEED NOT BE STRESS RELIEVED.

PAR. P-273. Revise to read:

(First three sections unchanged.)

After obtaining the code stamp the manufacturer of safety valves that are to be stamped with the Code symbol shall first submit at least three valves of each of three representative sizes of each design and for three different pressures for testing TOGETHER WITH DRAWINGS [at the plant of the manufacturer or] at a place where adequate equipment AND PERSONNEL are available to conduct pressure and relieving capacity tests WHICH SHALL BE MADE IN THE PRESENCE OF AN AUTHORIZED OBSERVER. THE PLACE, PERSONNEL, AND THE AUTHORIZED OBSERVER SHALL BE APPROVED BY THE BOILER CODE COMMITTEE.

Tests shall be made to determine the lift, popping, and blowdown pressures and capacity AT THREE DIFFERENT PRESSURES FOR EACH OF THREE REPRESENTATIVE SIZES OF EACH DESIGN. A COEFFICIENT SHALL BE ESTABLISHED FOR EACH TEST AS FOLLOWS:

$$K_D = \frac{\text{ACTUAL STEAM FLOW}}{\text{THEORETICAL STEAM FLOW}} = \text{COEFFICIENT OF DISCHARGE}$$

THE AVERAGE COEFFICIENT, K, OF THE NINE TESTS REQUIRED SHALL BE TAKEN AS THE COEFFICIENT OF THE DESIGN AND SHALL BE USED FOR DETERMINING THE RELIEVING CAPACITY OF ALL SIZES AND PRESSURES OF THE DESIGN IN THE FOLLOWING FORMULA:

FOR 45 deg SEAT $W = (51.45 \times \pi\ DLP \times 0.707 \times K)\ 0.90$

FOR FLAT SEAT $W = (51.45\ \pi\ DLP \times K)\ 0.90$

FOR NOZZLE $W = (51.45 \times AP \times K)\ 0.90$

WHERE W = WEIGHT OF STEAM PER HOUR, LB,
D = SEAT DIAMETER,
L = LIFT, INCHES,
P = (1.03 × SET PRESSURE) + 14.7 = ABSOLUTE PRESSURE, LB PER SQ IN.,
K = AVERAGE COEFFICIENT OF DISCHARGE,
A = NOZZLE THROAT AREA, SQ IN.

[for at least three points in the expected range of pressures and capacities for which the valve is to be used in order to establish the performance for each size and design].

(Sixth section unchanged.)

(Delete seventh section.)

A data sheet for each safety valve tested shall be filled out and signed by the manufacturer and BY THE AUTHORIZED OBSERVER [the inspector] witnessing the test (a sample data report appears on page 130). Such data sheet will be the manufacturer's authority to build and stamp valves of corresponding design and construction. When changes are made in the design, similar tests must be repeated.

(Ninth section unchanged.)

The data sheet appearing on page 130 will be revised so that the reference to "authorized inspector" will read "authorized observer."

PAR. P-300. Add the following to the third section:

When welded piping that is covered by this code is fabricated by anyone other than the manufacturer of the boiler, the welding shall be done by a fabricator in possession of the special code symbol for piping shown in Fig. P-44 1/2. For each connection this symbol shall be stamped on the pipe, valve, or fitting, adjacent to the welded joint farthest from the boiler. Such welded work shall be inspected by an authorized inspector at such stages

FIG. P-44 1/2 OFFICIAL SYMBOL FOR STAMP TO DENOTE A.S.M.E. STANDARD FOR WELDED PIPING

of the work as the inspector may elect. On completion of the work a partial data report shall be executed, on the basis of which the inspector of the final hydrostatic test may execute the field assembly certificate for the complete boiler.

PAR. A-19*a*. Change the range of fusion temperature from "400 to 500 F" to "445 to 450 F," as it appears in December, 1939, MECHANICAL ENGINEERING.

PAR. A-19*d*. Modify proposed revision of first sentence as it appears in December, 1939, MECHANICAL ENGINEERING, as follows:

Fusible plugs filled with tin as specified in (*a*) shall not be used FOR PRESSURES AND TEMPERATURES WHICH WILL CAUSE THE PLUG TO FAIL WHILE IT IS SUBMERGED IN THE BOILER WATER [with boiler water temperature in excess of 430 F].

PARS. A-100 to A-120, MA-1 to MA-10, UA-30 to UA-46. These paragraphs will be revised to conform to the latest American Welding Society Standard Qualification Procedure. Those desiring a copy thereof may obtain one upon application to the Secretary, Boiler Code Committee, in care of the Society.

Material Specifications Section. The following specifications will be revised to conform with the latest A.S.T.M. specifications, the designations of which are given in parentheses:

S-1 (A70-39), S-2 (A89-39), S-9 (A-96-39), S-23 (B42-39T), S-24 (B43-39T), S-25 (A129-39), S-26 and S-27 to be replaced by A212-39, S-28 (A202-39), S-33 (A157-39), S-35 (A182-39), S-36 (B96-39T), S-37 (B98-39), S-40 (A192-38T), S-42 (A201-39), S-43 (A203-39), S-44 (A204-39), S-45 (A206-39T), S-47 (B111-39T), S-51 (A194-39).

Specification S-52. This is a new specification which will be identical with A.S.T.M. Specifications A213-40T.

Specification S-53. This is a new specification which will be identical with A.S.T.M. Specifications A30-39.

Specifications S-54 and S-55. These are new specifications which will be identical with A.S.T.M. Specifications B126-39T and B127-39T and will be incorporated in the code when stress values have been established.

PAR. L-2.. Add the following:

S-53 Specifications for Boiler and Firebox Steel for Locomotives.

PAR. U-13*d*. Delete the last sentence.

PAR. U-36*c*. Insert the following as the second sentence:

When the joints in a multi-piece head come no closer to the center of a flanged-in manhole than a distance equal to the maximum diameter of the manhole, the added thickness required by this rule shall be based on the required thickness of a seamless blank head.

PAR. U-61*c*. Revise to read:

c When plates under 1/4 in. are formed into heads 36 IN. OR LESS IN [of small] diameter, etc.

PAR. UA-17*d*. Revise to read:

d All bolts and studs shall have THREADS AT LEAST AS STRONG AS American Standard [coarse] screw threads [provided that bolts and studs 1 1/8 in. in diameter and larger shall have eight threads per inch. A stronger form of thread may be used.].

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Operation Analysis

OPERATION ANALYSIS. By Harold B. Maynard and G. J. Stegemerten. McGraw-Hill Book Company, Inc., New York, N. Y., 1939. Cloth, 6 × 9 in., 290 pp., 107 figs., indexed, $3.

REVIEWED BY L. P. ALFORD[1]

AN oft-repeated and continuing criticism of scientific or industrial management is that its methods and practices lack, or fail to be based upon, engineering analysis. This book, the contents of which support its title, is further evidence of the falsity of this critical comment when applied to manufacturing operations. The authors, therefore, have rendered a real service to the still immature management movement, apart from the technical contribution made by their volume.

The treatment given to its topic in this book is, quite properly, "how to do it," the purpose being stated to be "to describe the procedure for conducting operation analysis."

After pointing out that the factors in even the simplest industrial operations are many and varied the following explanation of operation analysis is offered:

"During primary analysis, the operation is broken down into such general factors as material, inspection requirements, and working conditions. Each one of these factors is then examined minutely and critically in order to discover possibilities for improvement. This kind of analytical work is commonly understood to be covered by the term 'operation analysis,' and it will be discussed in considerable detail in the present volume."

To indicate the treatment adopted in carrying out the purpose of the book, the authors boldly attack the standard objection to management improvement—"our work is different," show its falsity, and go on to say, "For purposes of analysis, the methods engineer looks at an operation not as a single quantity but rather as a series of elemental operations."

Six types, or more properly techniques, of methods study are identified. Between certain of them there appears to be a distinction rather than a difference, and the groups might well have been reduced to three procedures with certain variations, namely, written job analysis, mental analysis, and standard data.

Chapters 6 through 20, the bulk of the book, are given over to a detailed presentation of the application of the methods and procedures of operation analysis. The treatment adopted is mainly the presentation of cases, analyzed in detail with the results of the analysis interpreted to show how improvement was obtained. Some of the results may seem startling to one who is unfamiliar with the possibilities of reducing production times by methods such as the authors advocate.

Every engineer knows the value of a check list in analysis work. Under the pressure of time, or other reasons for haste, it is easy to overlook some important question that should be asked and answered, or neglect some line of thought that should be pursued. The authors seek to meet this danger by devoting chapter 21 to the presentation of an extensive "operation analysis check list," which "lists all the questions that should be asked on each item on the analysis sheet and requires a definite answer to each question." Some 180 questions are included. A by-product use of this check sheet is to develop discussions in training courses for supervisors and key men in industry.

It is easy for the reviewer to wish that the first chapter had not been printed. Then the comment on page 10 that "Taylor was a white-collar man" would not have appeared, and certain questionable economic statements, in particular the chart on page 14, would not offend in an otherwise worthy book. The authors set out to reduce operation analysis to a specific, systematic procedure, capable of giving results in the form of methods improvement. This they have accomplished, and in so doing they have provided foremen, tool designers, inspectors, supervisors, and methods engineers with another tool in the art of industrial management.

[1] Chairman, Industrial Engineering Department, New York University. Fellow A.S.M.E.

Renaissance Engineering

ENGINEERS AND ENGINEERING IN THE RENAISSANCE. By William Barclay Parsons, with introduction by Nicholas Murray Butler, preface by John C. Merriam, and foreword by the editors, The Williams and Wilkins Co., Baltimore, Md., 1939. Cloth, 6 7/8 × 10 in., 661 pp., 211 illustrations and plates, appendixes, and index, $8.

REVIEWED BY J. W. ROE[2]

THIS is the most notable work in the field of engineering history since the publication, nearly thirty years ago, of the English translation of Agricola's "De Re Metallica" by Mr. and Mrs. Herbert Hoover. Seldom has the history of technology had the service of rare scholarship combined with the judgment which can come only with long experience in many fields of engineering practice. General Parsons, like Mr. Hoover, had this happy combination.

The records left by the early engineers have, with a few exceptions such as Leonardo, been few and meager. It is only in later years that the value of their work has been recognized. Historical writers have had little interest in it, and have not been equipped for sound appraisal of it. Trained engineers, who would appreciate the significance of this early work, have known little about it. This is not strange as the only records are inaccessible, buried in widely scattered libraries in old manuscripts and rare volumes, and written in various languages. Only long, patient labor can locate them and unravel their story. General Parsons was one of the few equipped to do this.

William B. Parsons was graduated from Columbia University in 1879 and received the graudate degree of C.E. in 1882. His active practice was wide, covering railroad engineering in China, subways and traffic problems in New York, London, and Chicago, and the Cape Cod and Panama canals. He was member and medalist of the great engineering societies here and abroad, and for many years chairman of the board of trustees of Columbia University. He was the author of four books which were based on his experiences in China and the

[2] Southport, Conn. Mem. A.S.M.E.

World War, and a life of Robert Fulton.

In addition to all this he spent many years collecting and sorting the material which appears in this book. It was unfinished at the time of his death in 1932, but the work was so far advanced that his family have prepared his notes for publication, thereby rendering a service to the engineering profession. Nothing has been added to General Parsons' original manuscript and notes, and little has been altered except where the phraseology required it. The book ends dramatically in the middle of a sentence, where the writer laid down his pen for the last time.

Owing to these circumstances the book as published is a collection of papers rather than a continuous story. Part one covers the spirit of the Renaissance which Parsons takes as from the fall of Constantinople in 1453 to the death of Queen Elizabeth in 1603. In three short chapters he traces the history of the various lines of force in church, politics, literature, and human restlessness and endeavor which met in the Renaissance. He lists the great names associated with it and points out that in this list none suggests to the average layman the engineer. There was, however, during this time, much engineering of high quality. Some of it was done by men who were called engineers, but more frequently by those rated as architects and artists and still so regarded.

One of the first and greatest of these was Leonardo da Vinci, born in 1452, just as the Renaissance was beginning. To him and to his work General Parsons gives seventy-five pages. Leonardo was unique in having left in his notes a detailed record of his widely ranging ideas. These notes begin in 1489 and continue until his death. Their strange history is one explanation of why he was not more fully recognized in his own time. He seems to have kept these notes always with him, and none were published during his lifetime. He willed them to a friend who guarded them closely for fifty years. At the death of this friend they fell into the hands of those who had little appreciation of their value. Of thirteen known volumes ten were taken to Florence and later given away, one went to the Ambrosian Library in Milan, and two have disappeared. Some have been cut up and combined into one volume which has had a checkered career. Other portions are in the South Kensington Museum, the British Museum, Windsor Castle, and the library of the Earl of Leicester, and fragments are in Rome, Turin, Florence, Venice, and elsewhere. Fifty-three hundred sheets are known to exist and it is certain that many others have been lost. They consist of notes written from right to left, with many abbreviations and hieroglyphs, and freely illustrated with his wonderful drawings.

These records show Leonardo as no dabbler. In every field he was the equal or superior of any master of his day. It is only in recent years, when patient research has brought together this record, that the full measure of this amazing mind has been recognized. Naturally, this book deals chiefly with Leonardo as a scientist and engineer, and his work in this field is traced with many quotations and reproductions of his sketches.

The next section, after a brief chapter on surveying in the Roman period, deals with invention and applications of machines. It points out that, although printing was invented in Germany and in 1470 there were five presses there and only two in Italy, that country overtook Germany and led for a generation. From 1480 to 1500 Italy had more printing presses than all the rest of Europe combined. In Venice alone there were 151 presses, three fourths as many as were in all Germany. It is interesting that Florence, where the Renaissance began, clung to its illuminated manuscripts and bitterly opposed the new art. For some reason there is little record of the origin and development of printing beyond the mass of material it produced. The old plates in this section of the book show printing presses, lifting devices, pumps, water wheels, drilling and file-cutting machines, dredges, and the first drawing of a railway car.

The section closes with a detailed account of the moving of the Vatican obelisk from the Circus of Nero to its present location in front of the Vatican. Fortunately, Fontana, who planned and executed the work, left a detailed record of it. The total weight of the obelisk and its slings was 737,680 lb. The efforts of over 900 men and 75 horses were coordinated by an elaborate system of pulleys. The operation was executed in a little less than five months, and the obelisk still stands as he placed it. This operation cannot, of course, be compared with that of the Romans who, instead of moving it 260 yards, took this same stone down, moved it to navigable water, loaded it on some form of vessel, carried it across the Mediterranean to Ostia, and thence to Rome, where they set it up. General Parsons, however, gives a full account of Fontana's work because of the wealth of detail the record presents. Probably nowhere is there a better account of how great weights were handled by men and animal power. It was a feat of real engineering and well done. It is a pity that the Roman engineer's work had no such record.

The third section, covering mining, metallurgy, and assaying, draws freely from "De Re Metallica" as translated by Mr. and Mrs. Hoover, and reproduces many of the plates from that book. Especially interesting is a table, prepared by Mr. Hoover, showing the developments in metallurgy from the period prior to recorded history down to 1500 A.D., giving the approximate order and dates.

Then follow sections on street lighting, traffic regulations, water supply and sewers, labor organizations, river engineering, locks and canals, and a history of the five early canals connecting the river systems of France.

The last part deals with structural engineering, with accounts of the bridges in Venice, Florence, and Paris, and closes with the design and building of the great domes of Santa Maria del Fiore in Florence and Saint Peter's at Rome. The last breaks off in the middle of a sentence as has been said. We wish the writer could have finished the story.

Several appendixes give the medieval weights and measures and various ordinances and edicts covering street cleaning, regulation of employment, trade organizations, and specifications for the canalizing of the River Auron.

We owe the editors a debt for having given us the result of General Parsons' years of research, and for the care with which it has been done. The result is an exceedingly valuable book and an enrichment of engineering literature.

Books Received in Library

ALLOYS OF IRON AND CHROMIUM, Vol. 2. High-Chromium Alloys. By A. B. Kinzel and R. Franks. Published for the Engineering Foundation by McGraw-Hill Book Co., Inc., New York, N. Y., 1940. Cloth, 6 × 9 in., 559 pp., illus., diagrams, charts, tables, $6. This is the final part of the review and summary of important published and available unpublished data on the alloys of iron and chromium prepared under the auspices of the Iron Alloys Committee of the Engineering Foundation. This section deals with alloys containing more than ten per cent of chromium, which include the corrosion-resistant and heat-resistant steels. The monograph affords a critical summary of research upon these alloys. A bibliography of over five hundred references is included.

AMERICAN MACHINISTS HANDBOOK and Dictionary of Shop Terms. By F. H. Colvin and F. A. Stanley. Seventh edition, revised and enlarged. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1940. Leather, 4 × 7 in., 1366 pp., diagrams, charts, tables, $4. The new edition of this well-known pocketbook for shopmen and draftsmen retains the plan of earlier editions, but it has been thoroughly revised and is larger by over 200 pages. Obsolete data have been replaced by new throughout the book, and sections have been rearranged. A large amount

of practical information on machining operations is provided.

A T M (Archiv für technisches Messen) Lfg. 100–102, October, November, December, 1939. R. Oldenbourg, Munich and Berlin, pp. T125–160. Paper, 8½ × 12 in., illus., diagrams, charts, tables, 1.50 rm each. Three numbers of a monthly publication containing classified articles upon various types of apparatus and methods for technical measurements.

COMPLETE WELDER, dealing with up-to-date methods of gas and electric welding. Three volumes. Vol. 1, Non-Electrical Methods, Design and Testing, 464 pp.; vol. 2, Electric Arc Welding, 432 pp.; vol. 3, Resistance Welding, 432 pp. George Newnes, Ltd., London, W.C.2, England, 1939. Cloth, 6 × 9½ in., illus., diagrams, charts, tables, £3 for three volumes. The three volumes of this set which are intended to cover every aspect of welding, are composed of articles contributed by specialists. The operation of equipment for all kinds of welding is explained, types of actual equipment on the market are described, and work under varying conditions and with different metals is discussed. All phases of the text are illustrated profusely with photographs and diagrams. Volume 3 contains a classified key and an alphabetical index to the whole work, and 28 miscellaneous data sheets are contained in a separate cover.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORIES OF HARVARD UNIVERSITY for the year 1938. Series II, vol. 5. Harvard University, Cambridge, Mass. Cloth, 8 × 11 in., illus., diagrams, charts, tables, $4. The papers collected in these volumes have previously appeared in various scientific journals during 1938 and 1939, and represent the activities of the laboratories in many fields of study.

CRACKING ART in 1938. (U.O.P. Booklet No. 239), edited by G. Egloff. Universal Oil Products Company, Chicago, Ill. Cloth, 6 × 9½ in., 458 pp., illus., diagrams, tables. This useful volume provides a comprehensive summary of the literature that appeared during the year 1938, with references to the sources. Research work, commercial cracking, plant equipment, the treatment of cracked products, the products and by-products obtained, and the production of high-octane fuel are considered. Brief abstracts of all domestic and foreign patents issued in 1938 are included, classed by subject.

EIDGENÖSSISSCHE MATERIALPRÜFUNGS- UND VERSUCHSANSTALT FÜR INDUSTRIE, BAUWESEN UND GEWERBE, Zürich, Switzerland. Bericht No. 97, 18 pp., 1939; 113, 30 pp., 1938; 115, 59 pp., 1939; 121, 32 pp., 1938; 122, 26 pp., 1939; 123, 22 pp., 1939. Paper, 8 × 12 in., illus., diagrams, charts, tables. These reports of the Swiss Federal Testing Laboratory cover, respectively, No. 97, formation and distribution of resin in the European larch; No. 113, investigations on alkyl-phenol-resin varnishes with special reference to their technological properties; No. 115, pressure drop and heat transfer with turbulent flow in smooth pipes with regard to nonisothermic flow; No. 121, problem of wear in rolling and sliding friction; No. 122, experiences with X-ray tested, welded pressure pipes and their safety factors; No. 123, tests of unreinforced, impregnated cement pipe.

ELEKTRISCHE KRAFTÜBERTRAGUNG. Vol. 3. Bau und Betrieb des Kraftwerkes. Part 2. By H. Kyser and K. H. Kyser. Third edition, Berlin, Julius Springer, 1940. Cloth, 6 × 9½ in., 616 pp., illus., diagrams, charts, tables, 57 rm. The present installment of the section in this treatise, which is devoted to the construction and operation of power plants, deals with the principles that determine the selection of continuous- and alternating-current generators, the operation of the latter in parallel, with switchgear and protective apparatus, and with the economic problems involved. The treatment is comprehensive, with emphasis upon principles rather than current forms of commercial equipment, and is intended to supply a practical text adapted to present needs. The volume completes this edition.

FORGING HANDBOOK. By W. Naujoks and D. C. Fabel. American Society for Metals, Cleveland, Ohio, 1939. Cloth, 6 × 9 in., 630 pp., illus., diagrams, charts, tables, $7.50. This volume fills a gap in technical literature by providing a comprehensive, practical treatise on forgings and forging practice, subjects upon which little has been written. The book discusses the questions involved in the design and equipment of forge plants, the production and finishing of forgings, testing, estimating, and cost accounting. Many manufacturers and organizations have assisted by supplying data.

SEMI-CONDUCTORS AND METALS. By A. H. Wilson. University Press, Cambridge, England; The Macmillan Co., New York, N. Y., 1939. Paper, 6 × 9 in., 119 pp., diagrams, charts, tables, $2. The purpose of this book is to provide a simplified authoritative account of some of the main achievements of the theory of metals in the last ten years, and thus to form an up-to-date supplement to the various treatises on the subject. The presentation aims to make clear the physical principles on which the theory is based and to derive the results wherever possible by simplified arguments. Brief bibliographies of recent publications are included.

SOCIAL SECURITY, Selected List of References on Unemployment, Old Age and Survivors', and Health Insurance, prepared by Helen Baker. Princeton University, Industrial Relations Section, Princeton, N. J., November, 1939. Paper, 6 × 9 in., 28 pp., $0.25. This selected list of references on unemployment, old age and survivors', and health insurance has been prepared as a tool for those seeking the facts about social-security problems, as the items were picked for their practical value.

SPANNUNGSOPTIK. By G. Mesmer. J. Springer, Berlin, Germany, 1939. Cloth, 6 × 9½ in., 222 pp., illus., diagrams, charts, tables; cloth, 30 rm.; paper, 28.50 rm. This book is intended as a concise introduction to the methods for the photoelastic study of stresses and to their practical uses in engineering. The fundamental mathematical derivations for stresses in a plane are worked out; the apparatus and methods for different processes are described and evaluated; dynamic and three-dimensional problems are briefly considered; and illustrated examples of actual work are presented. There is a large bibliography.

SYMPOSIUM ON THERMAL INSULATING MATERIALS. Columbus Regional Meeting, March 8, 1939. American Society for Testing Materials, Philadelphia, Pa., 1939. Paper and cloth, 6 × 9 in., 123 pp., illus., diagrams, charts, tables; paper, $1.25; cloth, $1.50. Four papers constitute this symposium, as follows: Factors influencing the thermal conductivity of nonmetallic materials; test methods for determining physical properties of thermal insulations; one consumer's problems in selecting heat insulation; effect of solar radiation on the heat transmission through walls. Discussion of the papers is included.

THERMODYNAMICS FOR CHEMICAL ENGINEERS. By H. C. Weber. John Wiley & Sons, Inc., New York, N. Y., 1939. Cloth, 6 × 9 in., 264 pp., illus., diagrams, charts, tables, $3.25. This textbook, intended for undergraduate instruction, aims to present the more important thermodynamic relations in a manner particularly useful to the chemical engineer. Emphasis is therefore placed on changes of a reversible, isothermal, nonflow nature, where analysis in terms of free energy is direct and satisfactory. Attention is also given, however, to changes where conditions approximate those of steady flow, where the use of the entropy concept is convenient, and to the correlation of the two different approaches.

TRANSPORTATION IN THE UNITED STATES. By T. W. Van Metre. Foundation Press, Chicago, Ill., 1939. Cloth, 6 × 9½ in., 403 pp., maps, tables, $3.75. Dealing chiefly with the railroads, this text first presents a rather extended historical treatment of their development in the United States, with some mention of canals and highways. The second part describes the organization, types of service, finance, and accounting of transportation agencies. The theory and practice of rate making occupy the third part, and in the fourth part the regulation of the transportation business is considered. Many references for additional reading are given.

TRANSFORMATOREN. (Sammlung Göschen, Bd. 952.) By W. Schäfer. Walter de Gruyter & Co., Berlin, Germany, 1939. Cloth 4 × 6½ in., 127 pp., illus., diagrams, charts, tables, 1.62 rm. The basic theory, types, and practical operation of transformers are discussed from an elementary viewpoint. The inclusion of many diagrams and photographs is an aid to the effective understanding of the subject matter.

V.D.I.-FORSCHUNGSHEFT 399, DIE FEINHEIT FESTER STOFFE UND IHRE TECHNOLOGISCHE BEDEUTUNG, by A. H. M. Andreasen. V.D.I. Verlag, Berlin, Germany, December, 1939. Paper, 8 × 12 in., 25 pp., illus., diagrams, charts, tables, 5 rm. The technological significance of the fineness of solid materials is discussed, covering both physicotechnical and chemical applications. The efficiency of various methods for the conversion of coarse material into fine, and also of fine into coarse in certain cases, is shown, the determination of fineness is explained, and the separation of sizes is briefly touched upon.

VOLUMETRIC AND PHASE BEHAVIOR OF HYDROCARBONS. By B. H. Sage and W. N. Lacey. Stanford University Press, Stanford University, Calif., 1939. Cloth, 6 × 9½ in., 299 pp., diagrams, charts, tables, $5. The phenomena discussed in this study are general in character, but the emphasis relates to hydrocarbons. The purpose is to set out for consideration the fundamental principles and some of the facts relating to that type of hydrocarbon behavior which does not involve chemical reactions or changes in the molecular species present, and to cases in which solid phases are absent. Application is found in certain processes of petroleum production, transportation and refining, and of natural-gasoline manufacture.

VORGÄNGE IN STRAHLAPPARATEN. (Beihefte zur Zeitschrift für die gesamte Kälte-Industrie, Reihe 2, Heft 8, edited by R. Plank.) By W. Weydanz. V.D.I. Verlag, Berlin, Germany, 1939. Paper, 6½ × 10 in., 139 pp., diagrams, charts, tables, 3 rm. The theory of the ejector as used in steam-jet refrigeration is discussed and the three major parts, the nozzle, mixing chamber, and diffuser are described, together with the processes in which they function.

A.S.M.E. NEWS

And Notes on Other Engineering Activities

Program Completed for A.S.M.E. Spring Meeting, Worcester, Mass., May 1–3, 1940

"City of Diversified Industries" Offers Visitors Opportunity to See Work of Mechanical Engineers

WORCESTER, the city of New England, which owes so much to the enterprise and vision of mechanical engineers in her establishment as the "city of diversified industries," will welcome hundreds of engineers from all parts of the United States and Canada to the 1940 Spring Meeting of The American Society of Mechanical Engineers, to be held at the Hotel Bancroft, May 1–3. The Honorable William A. Bennett, mayor of Worcester, and Admiral Wat Tyler Cluverius, president of Worcester Polytechnic Institute, will welcome the meeting participants at a general luncheon to be held at the hotel on Wednesday, May 1. President Warren H. McBryde will make the response in behalf of the Society.

Inspection Trips

Engineers will be given an opportunity to inspect the work of mechanical engineers in and about Worcester by means of visits which have been scheduled by the Plant Visits Committee to the city's outstanding plants. Because of the important work being carried on at all of these plants for the United States Government, only American citizens may take part in the inspection trips. Some of the things to be seen at the various companies to be visited in the afternoons include the following: Norton Company (May 1) will show the manufacture of grinding machinery and grinding wheels, from the tunnel kilns for vitrifying the product through the finishing departments to the shipping room; Rockwood Sprinkler Co. (May 1 and 3) among many features will offer a demonstration of the detection and fighting of fires in an air-conditioning system; Simonds Saw & Steel Co. (May 2) is famous throughout the world for its single windowless plant, five acres in area, through which the visitors will be conducted on an overhead walkway; Crompton & Knowles Loom Works (May 2) will show how it produces 20,000 looms a year in its 25-acre plant; John Woodman Higgins Armory (May 2) is a museum, library, and laboratory of pressed-steel products which should prove interesting to all visitors; Leland-Gifford Co. (May 3) is now engaged in the manufacture of drilling machines for the British and French governments; Baldwin-Duckworth Chain Co. (May 3) offers as the main feature among many attractions the manufacture of chains and sprockets designed for ammunition hoists on naval vessels; Wyman-Gordon Co. (May 3) manufactures all kinds of aircraft forgings; and Worcester Polytechnic Institute (May 3) will exhibit its foundry, manufacturing shop, and laboratories. There are many other plants not listed here which will be open to A.S.M.E. members and guests during the three-day meeting.

Galloway, N. Y.

THE COMMON AND THE CITY HALL, WORCESTER, MASS.

Social Events

At the general luncheon on Wednesday, May 1, the guest speaker will be Dr. John F. Tinsley, president of Associated Industries of Massachusetts, and president and general manager of Crompton & Knowles Loom Works. Following a cocktail hour on Thursday evening, May 2, the Spring Meeting Banquet will be held in the ballroom of the Hotel Bancroft. Admiral Cluverius, the toastmaster, will introduce the speaker of the evening, Ralph E. Flanders, past-president A.S.M.E., and president, Jones & Lamson Machine Co., who will present the "Progress Report of an Amateur Economist." Sociability is the word which expresses best the contents of the extra-special program prepared for the women attending the Meeting.

Technical Sessions

Fourteen simultaneous technical sessions are included in the program of the three-day meeting and will cover the subjects of management, steam power, industrial drying, machine-shop practice, fuels, boiler feedwater, hydraulics, iron and steel, heat transfer, and materials handling. All of the sessions will be held at the Bancroft Hotel with the exception of the iron and steel session, which takes place in the plant of the Worcester Pressed Steel Co., and the hydraulic sessions, that are scheduled for the Alden Laboratory of Worcester Polytechnic Institute. The titles of the technical papers, names of their authors, and the time of their presentation are contained in the following program:

A.S.M.E. Spring Meeting Program

Worcester, Mass., May 1–3, 1940

Headquarters, Hotel Bancroft

WEDNESDAY, MAY 1

10:00 a.m.

Management

A Personnel Program for a Small Plant, by Harold B. Bergen
Performance Rating of Employees, by C. R. Dooley

Power

Feedwater Treatment, by C. H. Fellows
Progress of Higher Pressures in the Industrial Plant, by W. F. Ryan

Process Industries

Experimental Drying, by D. L. Cooper
Conditioned Air in Drying and Curing of Tobacco, by A. H. Cooper

12:30 p.m.

General Luncheon

2:00 p.m.

Plant Visits

8:00 p.m.

Informal Reception at Worcester Art Museum

Machine Shop Practice

Deep-Hole Drilling by the Automatic Step Drilling Method, by Eric Hirvonen
High-Speed Photography and the Study of Rapid Machine Motions, by Victor Sepavich and Albert Palmer

Fuels—I

Successful Atomization (Mechanical) of Fuel Oil Heavier Than Bunker "C," by G. G. Martinson
Motion Pictures of Furnace Operation
(1) A. A. Markson, Consolidated Edison Co. of New York, Inc.
(2) O. F. Campbell, Sinclair Refining Co.
(3) Otto deLorenzi, Combustion Engineering Co., Inc.
(4) S. Konzo, University of Illinois

Galloway, N. Y.

FRANKLIN AND MAIN STREETS, WORCESTER, MASS., FROM CITY HALL

THURSDAY, MAY 2

9:30 a.m.

Fuels—II

Purchase and Use of Fuels, by E. Wadsworth Stone
Effect of Coal Characteristics on Pulverized-Coal Firing, by Ollison Craig
Recent Developments in Oil Burning, by R. C. Vroom

Boiler Feedwater

Determination of the Purity of Steam, by M. C. Schwartz, W. B. Gurney, and Thomas E. Crossan
Discussion on Paper by R. E. Hall and E. P. Partridge—Attack on Steel in High-Pressure Boilers as a Result of Overheating Due to Steam Blanketing (presented at 1939 Spring Meeting in New Orleans)

10:00 a.m.

Hydraulic—I

Alden Hydraulic Laboratory

Salt-Velocity Measurements at Low Velocities in Pipes, by L. J. Hooper
Field Checks of the Salt-Velocity Method, by O. H. Dodkin (to be presented by C. W. Hubbard)
Inspection of Alden Hydraulic Laboratory

1:00 p.m. Hydraulic Division Luncheon at Alden Laboratory followed by continuation of Hydraulic Session—I Movies of Model Tests

2:00 p.m.

Plant Visits

10:00 a.m.

Iron and Steel—I

Worcester Pressed Steel Company Plant

The Forge of Vulcan, by John W. Higgins
The Aluminum Alloy Aircraft Dome, by Harold T. Burke
The Pressed Steel Industry, by Carter C. Higgins

1:00 p.m. Iron and Steel Division Luncheon at Worcester Pressed Steel Co. Cafeteria

Galloway, N. Y.

MAIN AND FRONT STREETS, WORCESTER, MASS., HEART OF RETAIL DISTRICT

2:30 p.m.

Inspection of John Woodman Higgins Armory and Worcester Pressed Steel Company plant

6:30 p.m.

Cocktail Hour

7:00 p.m.

Banquet

FRIDAY, MAY 3

9:30 a.m.

Heat Transfer

Thermodynamic Properties of Vapors, by Eric Leib
The New Specific Heats, by R. C. H. Heck
Properties of Hydrogen Mixtures, by A. W. Brunot

9:30 a.m.

Materials Handling

Modern Developments in Materials Handling, by Russell Hastings
Machine-Tool Transfer Methods, by A. L. Wilkinson

Iron and Steel—II

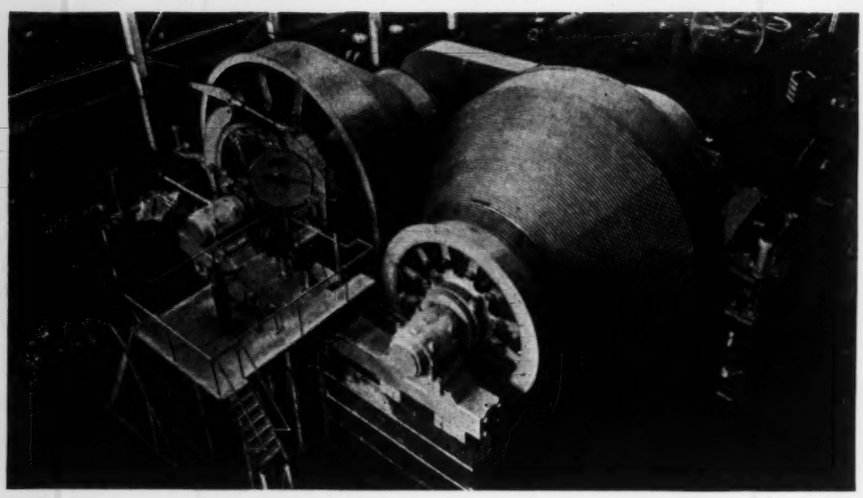
Factors in the Fatigue of Helical Springs, by R. R. Tatnall
Combined Tension-Torsion Tests on 0.35 Carbon Steel, by Evan A. Davis

Hydraulic—II

Progress Report on Cavitation Research at M.I.T., by B. G. Rightmire
Cavitation of Hydraulic-Turbine Runners, by R. E. B. Sharp

2:00 p.m.

Plant Visits



OUTSTANDING DOUBLE-DRUM HOIST AT THE PLANT OF THE NORDBERG MANUFACTURING COMPANY IN MILWAUKEE

(This plant is on the list of those to be visited during the A.S.M.E. Semi-Annual Meeting at Milwaukee, June 17–20.)

A.S.M.E. Semi-Annual Meeting in Milwaukee, Wis., June 17-20, 1940

Industrial Developments in Midwest to Be Featured in Technical Sessions and Many Inspection Trips

A REVIEW of the latest developments in industry and engineering in the Midwest is to be made in the many technical sessions scheduled for the 1940 Semi-Annual Meeting of The American Society of Mechanical Engineers, which is to be held in Milwaukee, Wis., June 17–20, with headquarters at the Hotel Pfister. Supplementing the engineering papers will be the visits to some of the outstanding manufacturing plants in the country which are located in Milwaukee. The city is particularly noted for the development of heavy machinery that can be found the world over in practically all fields of industry.

Social Activities

But all work and no play would make a very dull meeting. Therefore, the General Committee in charge of the Meeting is already making arrangements to provide visitors with facilities for golf, tennis, and other recreational facilities. There will be luncheons, dinners, and a formal banquet. Those desiring to do so can sample the beer and food for which Milwaukee is famous. A few of the traditional German dishes to be found in some of the restaurants are munchner, kalbshaxen, sauerbraten with dumplings, deutscher pfannkuchen, hasenpfeffer, koenigsberger klops, Hungarian goulash, schweine schenkel, and sauerkraut. During the four-day meeting, the Milwaukee breweries will be open for inspection at any time during the day, including the Pabst Blue Ribbon and Schlitz plants. Other points of interest to A.S.M.E. members and women include the many educational institutions, the Museum which contains one of the largest collections of prehistoric Indian artifacts in the world, the Layton Art Gallery Milwaukee Art Institute, Washington Park Zoo which is the only zoo in America or Europe that has been successful in raising polar-bear cubs, and the Mitchell Park Conservatory that contains an all-year flower show. If any of the visitors like sailing, a number of sailboats will be available for their use on beautiful Lake Michigan.

Technical Sessions

It is intended to have one or more sessions on each of the following subjects: fuels, heat transfer, flow of water, hydraulic equipment, machine-shop practice, management, steam turbines, power plants, steam power, and symposium on steam-locomotive valves and valve mechanism. Some of the papers to be presented at these sessions include the following by A.S.M.E. members:

"History of Pulverized Coal," by Henry Kreisinger, Combustion Engg. Co., and John Blizard, Foster Wheeler Corp.

"Flow of Water in Curved Sections," by William M. White, Allis-Chalmers Manufacturing Co.

"Flow Through Turbines and Pumps," by J. R. Weske, Case School of Applied Science

"Centrifugal-Pump Efficiency Measurements," by R. W. Angus, University of Toronto

"A New Method of Tool and Die Milling," by Francis J. Trecker, Kearney & Trecker Corporation

"Power and Velocity Developed in Manual Work," by C. A. Koepke and L. S. Whitson, College of Engineering, University of Minnesota

"Progress in Design and Performance of Modern Large Steam Turbines," by G. B. Warren, General Electric Co.

"Turbine Blade Fatigue Testing," by R. P. Kroon, Westinghouse Electric & Manufacturing Co.

"Efficiencies Realizable From Large Modern Steam Turbines," by G. B. Warren and P. H. Knowlton, General Electric Co.

"Study of Heat Insulation Problems in Power Plants," by E. T. Cope, The Detroit Edison Co.

"Experience With Metals at High Temperatures," by A. E. White, University of Michigan

"Development of a Major Principle in Pulverized-Coal Firing," by F. L. Dornbrook, Wisconsin Electric Power Co.

"Redesign of Piston Valves as a Means of Modernizing Steam Locomotives," by F. G. Lister, St. Louis and San Francisco R.R.

"Valve and Valve-Motion Design for Modern High-Speed Passenger Steam Locomotives," by A. G. Hoppe, Chicago, Milwaukee, St. Paul & Pacific R.R. Co.

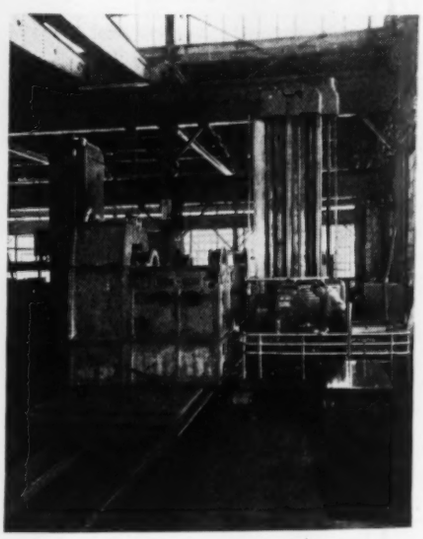
"Measurement of Cylinder Power of High-Speed Passenger Locomotives," by L. K. Botterson, Union Pacific Railroad Co.

Inspection Trips

Although the accent will be on heavy-machinery plant trips during the Semi-Annual Meeting, there are many other types of manufacturing plants which will be open to A.S.M.E. members and guests. Some of both types of plants to be visited include:

The Falk Corporation, which manufactures commercial herringbone and single helical gears, parallel-shaft and right-angle gear reducers, flexible couplings, large marine turbine and Diesel-engine gear drives, steel castings, and welded equipment.

Milwaukee Sewage Disposal Plant, which



HOUSING FOR LARGE MARINE GEAR DRIVE BEING MILLED ON COMBINATION BORING BAR AND MILLING MACHINE AT PLANT OF THE FALK CORPORATION

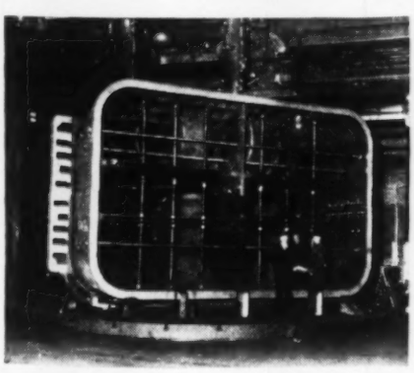
(This plant is one of those to be visited during the A.S.M.E. Semi-Annual Meeting in Milwaukee, June 17–20.)

disposes of 120 million gallons of sewage a day.

Nordberg Manufacturing Company, whose products include steam engines, steam-driven equipment, Diesel engines, air compressors, crushers, screens, and machinery for the maintenance of railroad track.

Wisconsin Electric Power Company, which owns the world-famous Port Washington high-pressure, high-temperature power plant that established a new record in 1939 for efficiency of operation with a heat consumption of 10,770 Btu per kwhr of station output while operating at a 59 per cent of annual load factor and an availability of 90.2 per cent.

Allis-Chalmers Manufacturing Co., which is sometimes called the Krupp plant of North America, because of its varied activities that include the manufacture of machines and equipment ranging from the smallest to the largest in the world.



40-FOOT BORING MILL IN WEST ALLIS WORKS OF THE ALLIS-CHALMERS MANUFACTURING COMPANY, MILWAUKEE. SHOWS EXHAUST END OF 60,000 KW, 1800 RPM STEAM TURBINE ON MILL

(One of the plants scheduled for an inspection trip during the A.S.M.E. Semi-Annual Meeting in Milwaukee, June 17–20.)

Actions of A.S.M.E. Executive Committee

AT A meeting held in the rooms of the Society, the Executive Committee of the Council of The American Society of Mechanical Engineers took several actions that are of general interest. There were present President Warren H. McBryde, chairman; James W. Parker, Kenneth H. Condit, and Clarke Freeman, of the committee; J. N. Landis (Local Sections) and Harte Cooke (Professional Divisions), advisory members; and C. E. Davies, secretary.

Acceptance was voted, with appreciation, of the resignation of D. Robert Yarnall as A.S.M.E. representative of the United Engineering Trustees, Inc., and Walter Kidde was appointed to fill the unexpired term.

The Secretary was authorized to participate, with Harvey N. Davis, past-president, in the preparation of a report on work performed by mechanical engineers in industrial research in the United States, as part of a larger report on industrial research as a national resource, which is being prepared by the National Research Council and the National Academy of Science for the National Resources Board.

Upon recommendation of the Committee on Research, the Executive Committee voted to discharge the Special Research Committee on Velocity of Fluid Flow, inasmuch as the work of that committee had been completed.

Upon the recommendation of the Board of Honors and Awards it was voted to comply with the request of the American Chemical Society and endorse the election of Charles Goodyear to the Hall of Fame.

Cosponsorship by the A.S.M.E. Management Division in the Purdue Management Conference, May 1–3, 1940, was authorized.

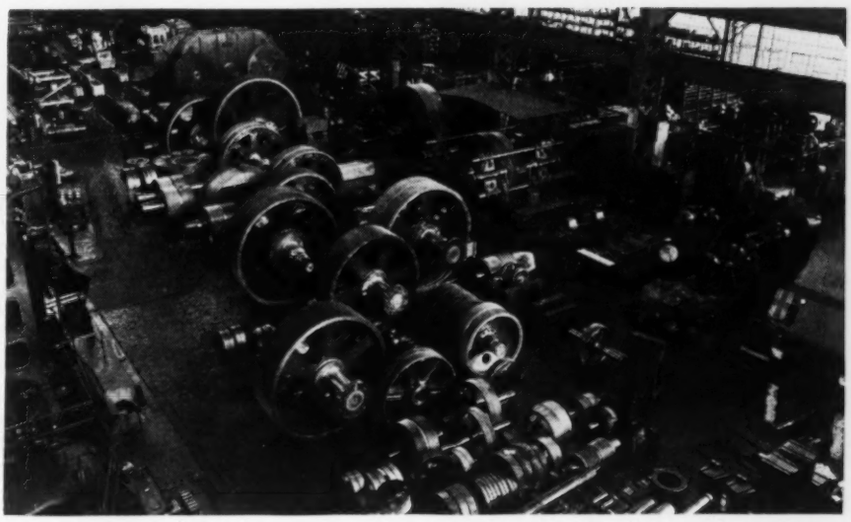
The Committee accepted, with appreciation, a bound volume of anecdotes and reminiscences by associates of George Westinghouse, gathered by Charles F. Scott to commemorate the ninetieth birthday of Mr. Westinghouse.

Prof. Manuel S. Vallarta, associate professor of physics at the Massachusetts Institute of Technology, was appointed the Calvin W. Rice lecturer for 1940.

James H. Herron and Erik Oberg were appointed Council advisers to the Woman's Auxiliary for 1940.

Conrad N. Lauer, W. L. Batt, and L. K. Sillcox were appointed honorary vice-presidents to represent the Society at the funeral services of Samuel M. Vauclain, honorary member A.S.M.E., who died on Feb. 4, 1940.

The following appointments were reported for record: Committee on Publications, O. B. Schier, 2nd, alternate for Coleman Sellers, 3d; Executive Committee, Management Division, Jas. M. Talbot; Research Special Committee on Fluid Meters, E. O. Bennett; Boiler Code Subcommittee on Ferrous Materials, W. R. Grunow, N. L. Mochel, and R. Wilson; Fuels Division, Model Smoke Law Committee, J. F. Barkley, chairman, A. G. Christie, O. F. Campbell, W. G. Christy, T. A. Marsh, T. E. Purcell, R. A. Sherman, R. R. Tucker; American Academy of Political and Social Science, annual meeting, Philadelphia, April 12–13, 1940, E. L. Hopping, L. N. Gulick, and L. P. Hynes.



ASSEMBLY FLOOR FOR LARGE GEAR DRIVES WITH GROUP OF GEARS FOR MARINE UNITS IN FOREGROUND—AT THE PLANT OF THE FALK CORPORATION, MILWAUKEE

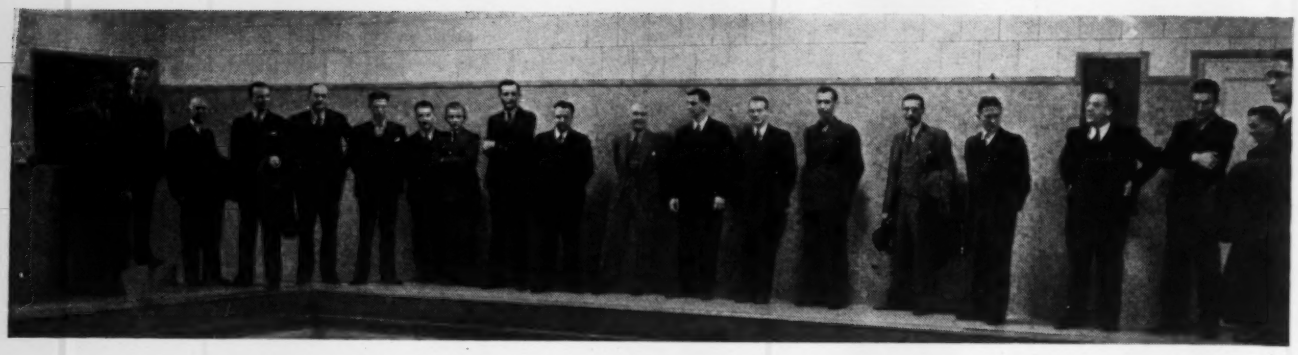
(Plans are being made to visit this plant during the A.S.M.E. Semi-Annual Meeting at Milwaukee, June 17–20.)

D. C. Jackling Voted 1940 Washington Award

THE Washington Award Commission has elected Daniel Cowan Jackling, past-president of the A.I.M.E., as the recipient of the 1940 Washington Award in recognition of pre-eminent service in advancing human progress "by pioneering in large-scale mining and treatment of low-grade copper ores releasing vast resources from formerly worthless deposits." The award, in the form of a certificate and a plaque, will be presented to Dr. Jackling at a dinner on Monday evening, April 15, in the grand ballroom of the Drake Hotel, Chicago, Ill. The four Founder Societies will be represented by special representatives to be appointed, and former recipients have been invited to attend as guests of the Commission. B. F. Affleck, chairman of the Commission, will preside and L. R. Mapes, president of the Western Society of Engineers, will make the presentation.

Dr. Jackling's experience as a mining engineer began in the Cripple Creek District of Colorado where he worked as a chemist and metallurgist from 1894 to 1896. In 1896, he went to Mercur, Utah, to conduct experimental work on refractory ores. His research, based upon the roasting of the ore before cyanidation, was so successful that a 500-ton mill was built and completed in 1898. In the same year, he made a report upon the copper mines of Enos Wall, at Bingham, Utah, which disclosed for the first time the possibility of profitable exploitation of low-grade porphyry ore. This resulted in the formation of the Utah Copper Company in 1903, with Dr. Jackling as the first manager, becoming later on, successively, managing director and president, which position he still holds today.

The Washington Award Commission is made up of representatives of the A.S.C.E., A.I.M.E., A.S.M.E., A.I.E.E., and Western Society of Engineers. Representing the A.S.M.E. are C. B. Nolte and W. L. Abbott.



C. A. CANNON, PRESIDENT OF THE CANNON MILLS, PROUDLY SHOWS MEMBERS OF A.S.M.E. CHARLOTTE SECTION THROUGH NEW Y.M.C.A. AT KANNAPOLIS, N. C., AND THEN PERSONALLY CONDUCTS THEM THROUGH THE MILL

Sixtieth Anniversary of Founding of A.S.M.E. to Be Celebrated in April by Local Sections

Special Meetings and Dinners Will Be Occasions for Re-Emphasizing Part Played in Industry by A.S.M.E. Members

IN THE MONTH OF APRIL, The American Society of Mechanical Engineers, through its 71 Local Sections located in the chief industrial centers of the United States and Canada, will mark its founding and sixty years of service to engineers, industry, and the public. Since the organization meeting of the Society took place on April 7 in the assembly room of Stevens Institute of Technology in Hoboken, N. J., back in 1880, such developments as the steam turbine, internal-combustion engine, automobile, airplane, lightweight trains, high-pressure and high-temperature steam generators, modern steel and alloy production, scientific management, and welding, are some of the contributions made by members to modern industrial civilization during a period from which the membership grew from less than a hundred to the present 15,000 members and 6500 student members.

Sixty-Year Members

Four members who joined the Society in 1880 are still on the roll and will now become the first sixty-year members. They are P. B. de Schweinitz, retired professor of Lehigh University, who resides in Bethlehem, Pa.; Henry Marx, who is still active as president of G. A. Gray Co., Cincinnati, Ohio; Albert W. Smith, dean emeritus, Sibley College, Cornell University, who lives in Ithaca, N. Y.; and Edward N. Trump, past vice-president of the Society, and now treasurer and engineer, Sanitary Metal Cap Corp., Syracuse, N. Y. It is interesting to note that, according to available records, the last three members were students at Cornell University.

Local Sections Celebrations

Practically every one of the 71 Local Sections of the Society will hold some kind of meeting or affair during April to commemorate this great event. Most of these events are scheduled for the week beginning April 7, as shown in the list of coming meetings of Local Sections published on page 351 of this issue.

New York City members are contemplating a special ceremony on April 8 in Washington Square Park where a wreath will be placed upon the statue of Alexander Lyman Holley, one of the founders of the Society and honorary member in perpetuity.

Metropolitan's Spring Round-Up

The largest Section in the Society, the Metropolitan Section, will celebrate not only the anniversary of the A.S.M.E., but also its thirtieth anniversary at the second annual Spring Round-Up, to be held Thursday, April 25, at the Hotel Astor in New York City. From 2:30 to 5:30 in the afternoon, there will be presented five half-hour papers by outstanding speakers on the subject of "National Defense and Mechanical Engineering." Howard Coonley, chairman of the board, National Association of Manufacturers, will act as chairman. Then, from 5:30 to 7:30, a cocktail hour will be held in order to give members and guests an opportunity of renewing old friendships and of making new ones.

This will be followed by an informal banquet, which will feature turkey with all the trimmings. The guest of honor will be Warren H. McBryde, President of the Society, who will say a few words of interest to all members. Frank W. Smith, director and past-president, Consolidated Edison Co., Inc., will serve as toastmaster. Top-notch entertainers in the fields of radio, screen, and stage have been engaged to finish off the evening with several hours of entertainment. Because of limited space, the number of reservations for the affair cannot exceed 800.

Pittsburgh's Engineering Day

The Pittsburgh industrial area's engineers have been invited to attend the April session of the Pittsburgh Section, which will be an all-day engineering meeting, Tuesday, April 23, at the William Penn Hotel. Three simultaneous technical sessions are scheduled for both the morning and the afternoon plus an "Engineers' Luncheon" at noon. The program for the day follows:

9:15 a.m.

Hydraulic

Hydraulic-Press Designs and Controls, by R. W. Andrews, Aluminum Co. of America

High-Pressure Hydraulic Pumps, Piping, and Fittings, by J. E. Holveck, Worthington Pump & Manufacturing Co.

Management

Supervisory Training, by Herbert L. Badger, Bell Telephone Co. of Penn.

Good Management and Good Industrial Relations, by William Conover, U. S. Steel Corp.

General

Economic Advances in Transportation Due to Reduction of Weight by Design and Modern Materials, by L. E. Endsley, consulting engineer

Mechanized Army, by U. S. Army officer

12:15 p.m.

Engineers' Luncheon

The Story of Polarized Glass (Polaroid), by Dr. L. W. Chubb, director of Westinghouse Research Laboratories

2:00 p.m.

Power

Large Steam-Turbine Design Practice, by R. C. Allen, Allis-Chalmers Mfg. Co.

Boiler Design, by Martin Frisch, Foster Wheeler Corp.

General

Value of Plastics to the Mechanical Engineer, by E. R. Perry, Westinghouse Electric & Manufacturing Co.

Modern Machining of Metals, by J. P. Gill, Vanadium Alloys Steel Co.

Oil Industry

Effect of Oil Lubrication Properties of Recent Refinery Developments, and Effect on Oil Fuels of Recent Refinery Developments, by Eugene Ayers and R. J. S. Pigott, Gulf Research Corporation.

CHARLOTTE SECTION HAS DINNER AT THE NEW Y.M.C.A. · C. A. CANNON AND W. W. LE ROY, CHAIRMAN OF THE SECTION, ARE AMONG THOSE AT THE SPEAKERS' TABLE

Industrial Mobilization at Anthracite - Lehigh Valley

Meeting at Scranton, Feb. 23, members of the Anthracite-Lehigh Valley Section heard Capt. W. S. Broberg, U. S. Army, describe "Our Industrial Mobilization Plan." After presenting a digest of the reports of some 2000 agencies of the World War, he discussed in turn the economic factors that are basic for wars, the weaknesses uncovered in 1917–1918, and how "war resources administration" in case of an emergency would coordinate all activities and avoid pitfalls of the last war.

260 Attend Baltimore Section Meeting on U.S.S. "Squalus"

The rescue and salvage operations in the raising of the U.S.S. *Squalus* were described to more than 260 members and guests of the Baltimore Section on Feb. 13 by Lieut.-Com. A. M. Morgan. The talk outlined the operations of the U.S.S. *Squalus* leading to the sinking, the rescue operations, and the salvage work. Features of the submarine bearing on the problem and the solution of it were fully covered. The speaker answered all questions at the end of his talk except on those subjects which he was unable to divulge because of naval secrecy.

E. G. Bailey Talks Before Central Pennsylvania Section

E. G. Bailey, member A.S.M.E., was the guest speaker at the Feb. 16 meeting of the Central Pennsylvania Section at State College, Pa. He discussed the burning of fuel and the absorption of heat in modern boiler units.

Charlotte Section Holds Its Meeting in Kannapolis, N. C.

On Feb. 9, the Charlotte Section held a meeting at Kannapolis, N. C. C. A. Cannon, president of the Cannon Mills Co., was the speaker. He gave a very interesting explanation of the growth and shrinkage of the textile industry in the last few years. The meeting was closed with a conducted tour of the Cannon mills, the largest towel-manufacturing plant in the world. The accompanying photographs were taken of the group in attendance.

Cincinnati Discusses Importance of Design and Material

H. W. McQuaid, assistant chief metallurgist, Republic Steel Corporation, was the guest speaker at the Feb. 15 meeting of the Cincinnati Section. He stressed in his talk the importance of design for dynamic loads, rigidity, and low stress concentration. The effect of heat-treatment on grain structure and physical properties of steel was explained. Slides showing curves and photographs were used to illustrate the paper.

Colorado Section Is Guest of A.S.M.E. Student Branch

On Feb. 23, the Colorado Section members were guests of the Colorado School of Mines Student Branch of the A.S.M.E. at a meeting which was addressed by Prof. John C. Reed on the subject of "Flow of Water in Glass Pipe at Various Velocities." The flow lines of water flow were photographed on motion-picture film in order to show the laminar flow at low velocity and the changes in eddies and waves as velocity increased in the turbulent regions. According to R. F. Throne, secretary treasurer of the Section, this was the most interesting meeting held this year.

Wages and Hours Act Is Topic at Columbus Section Session

The topic at the Feb. 23 meeting of the Columbus Section was the Wages and Hours Act. Ralph P. Ward, Ohio Chamber of Commerce, discussed the act from the viewpoint of the employers, and DeWitt Huffman, Ohio Federation of Labor, presented the reactions of labor.

Detroit Section Holds Closed Meeting for Members Only

The Feb. 6 meeting of the Detroit Section in the Ford Rotunda was a meeting for A.S.M.E. members only. Consequently, several hundred members turned up and crowded into all the space that was available. The subject, coal handling, was discussed by H. L. Parr and G. C. Daniels. In order to avoid the charge of favoritism, the speakers were not allowed to mention the names of manufacturers of any equipment that was described.

East Tennessee Section Meets in Knoxville

The cafeteria of the University of Tennessee in Knoxville, Tenn., was the scene of the Feb. 17 meeting of the East Tennessee Section. James T. Potter and Leonard Highley discussed the subject of conditioning of boiler water.

Fort Wayne Members Hear Paper on Superfinish

On Feb. 15, the Fort Wayne Section presented a talk on "superfinish" by Mr. Hutcheson, Chrysler Corporation. It was one of the best meetings of the year.

M. C. Maxwell Talks on Home Defense at Greenville

Stating that locks are a means of home defense, Maxwell C. Maxwell told members and guests of Greenville Section on Jan. 6 about the history and modern development of locks.

Von Kármán Talks to 185 Los Angeles Engineers

In spite of a broken arm, Theodore von Kármán, member A.S.M.E., did a wonderful job at the Feb. 8 meeting of the Los Angeles Section in explaining "Mathematics From the Viewpoint of the Engineer." The other speaker, E. T. Bell, discussed the topic from the viewpoint of the mathematician. Prof. R. L. Daugherty acted as chairman of the meeting which was attended by 185 members and guests. Dr. Bell in his talk made the statement that "the engineers of today are building the foundations for the engineers of tomorrow, while the mathematicians of today are building the foundations for the scientists of tomorrow." Dr. von Kármán kept the audi-

ence rocking with laughter with his verbal bombardments of the exactness required by the pure mathematician as against the close approximation that is used by the engineer. His extremely simple illustrations of rather complex mathematical equations used by research engineers and others left no doubt in the minds of the audience why this man is one of the foremost engineers in America today. Dr. von Kármán's paper appears as the leading article in this issue.

Mid-Continent Section Hears Maxwell C. Maxwell

The guest speaker on Feb. 13 before the Mid-Continent Section was Maxwell C. Maxwell. His talk, entitled "Home Defense," concerned itself with the story of locks from 1000 A.D. to the present time.

Pertinent Facts About Oil Considered at Minnesota

Minnesota Section held a meeting at the University of Minnesota on Feb. 26. The speaker of the evening was Marshall A. Peterson, chief chemist of the Minnesota State Highway Department, who spoke on "Pertinent Facts About Oils." Consideration was given to the qualities of various types of oils involved in commercial use, including gasolines, fuel oils, and lubricating oils.

Welded Design Is Subject of Oregon Section Meeting

Leon C. Bibber, welding engineer, Carnegie-Illinois Corporation, talked to the Oregon Section, Feb. 16, on the basic principles of welded design and the most frequent reasons for welding failures due to faulty or inadequate design. The paper was illustrated with a series of slides depicting full-size experiments.

Philadelphia Session on Research Attended by 275

A dinner, followed by a general meeting, was held by the Philadelphia Section on Feb. 27. There were 130 at the dinner and 275 at the meeting. Dean E. LeRoy Mercer, University of Pennsylvania, gave a coffee talk on hobbies. M. W. Smith, vice-president in charge of research, Westinghouse Elec. & Mfg. Co., outlined the scope of research carried on by his company. He was followed by F. T. Hague, of the same company, who discussed with the aid of slides and models the research project now being carried out on superposed-turbine blades jointly with the Philadelphia Electric Co. (See page 275 of this issue of MECHANICAL ENGINEERING for Mr. Hague's paper.)

Rock River Valley Meeting on Metals Attracts 300

Rock River Valley Section held a meeting on Feb. 23 which was attended by more than 300 members and guests. A paper on "Metals Versus Nonmetals" was presented by A. Allen Bates, Westinghouse Research Laboratories. He discussed the newer types of structural materials developed by the chemical, ceramic, and other nonmetallurgical industries. Utilization of various materials was illustrated with samples.

PHILADELPHIA MEMBERS AT PREVIEW OF STEAM TURBINE

(Members of the Philadelphia Section gathered on Feb. 27, 1940, for a preview of an experimental steam turbine at the Schuylkill Plant of the Philadelphia Electric Co. Tests to determine conditions in blading of turbine are being conducted jointly by engineers of the company and the Westinghouse Elec. & Mfg. Co.)

A.S.M.E. Calendar

of Coming Meetings

May 1–3, 1940
Spring Meeting
Worcester, Mass.

June 17–20, 1940
Semi-Annual Meeting
Milwaukee, Wis.

June 19–22, 1940
Oil and Gas Power Division
Asbury Park, N. J.

June 20–21, 1940
Applied Mechanics Division
Ann Arbor, Mich.

September 3–6, 1940
Fall Meeting
Spokane, Wash.

December 2–5, 1940
Annual Meeting
New York, N. Y.

(For coming meetings of other organizations see page 24 of the advertising section of this issue)

A.S.M.E. Section Represented on St. Louis Smoke Committee

Dean A. S. Langsdorf and Robert M. Boyles of the St. Louis Section were appointed to a special committee for the 1940 Smoke Prevention Association Convention by the mayor of St. Louis. At the Feb. 23 meeting of the Section, Major H. M. Reedall, U. S. Army, talked on the subject of "Industrial Mobilization."

Color Photography Is Subject of San Francisco Meeting

Members of the San Francisco Section learned all about color photography and the construction of color cameras from Dr. Thomas S. Curtis at the Feb. 29 meeting. The 130 members and guests were given a comprehensive description of the system underlying the production of photographs in color, nature of requirements, physics, and optical conditions. Since this meeting was also in the nature of a special leap-year party, 52 women were present at the dinner and in attendance at the meeting afterward.

Present Status of Television Discussed at Waterbury

Donald W. Pugsley, engineer, General Electric Co., gave a paper on Feb. 21 before the Waterbury Section on "The Present Status of Television." He illustrated his lecture with lantern slides and with demonstrations of television receivers.

A.S.M. President Is Guest of Western Washington Section

James P. Gill, president of the American Society for Metals, was the guest speaker at the Feb. 13 meeting of the Western Washington Section of the A.S.M.E. An audience of 75 members and guests heard his talk on the "Machining of Metals."

A.S.M.E. Chicago Section Helps in Midwest Power Conference

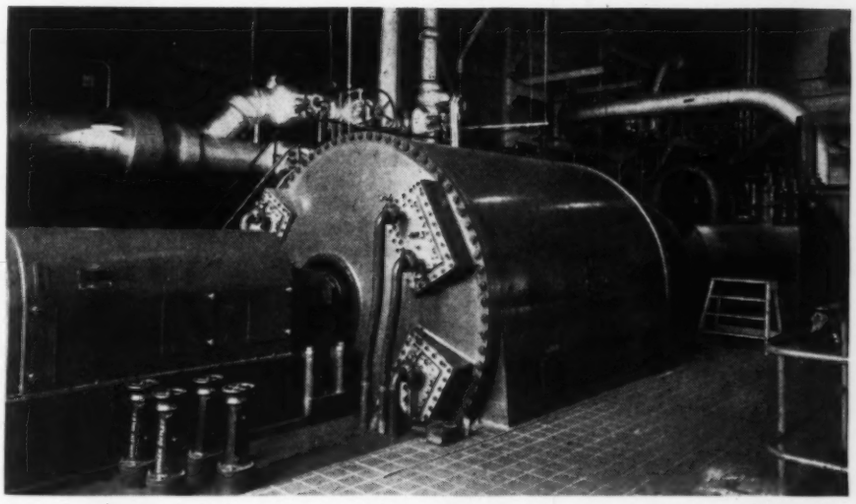
SPONSORED by Armour Institute of Technology with the cooperation of the A.S.M.E. Chicago Section and other institutions and technical organizations, the 1940 Midwest Power Conference takes place at the Palmer House, Chicago, Ill., April 9–10. Out of the 22 speakers scheduled for the various sessions, 18 are A.S.M.E. members. The latter include Loran D. Gayton, city engineer of Chicago; Prof. Ben G. Elliott; Philip W. Swain, editor of *Power;* Paul R. Sidler, resident engineer of Brown, Boveri & Co.; Herbert W. Dow, Nordberg Manufacturing Co.; Philip Sporn, American Gas and Electric Service Corporation; Grover Keeth, Marathon Paper Mills Co.; R. L. Meyer, Standard Oil Co.; Alex D. Bailey, Commonwealth Edison Co.; F. Malcolm Farmer, president of A.I.E.E.; James W. Parker, vice-president of A.S.M.E.; John M. Drabelle, consulting engineer; Martin Frisch, Foster Wheeler Corporation; H. A. Kleinman, Peoples Power Co.; E. L. Tindall, Carnegie-Illinois Steel Corporation; L. F. Harza, Harza Engineering Co.; James S. Bowman, T.V.A.; and L. W. W. Morrow, McGraw-Hill Publications.

Canadian Provinces Adopt Parts of A.S.M.E. Boiler Code

ORDERS-IN-COUNCIL were recently passed by the governments of the Canadian Provinces of Ontario and Manitoba ordering the official adoption of parts of the A.S.M.E. Boiler Code dealing with the following subjects: Power boilers, low-pressure heating boilers, miniature boilers, unfired-pressure vessels, and rules for the care of power boilers.

C. L. Combes Is Appointed Railroad Division Secretary

UPON the resignation of M. B. Richardson in February as secretary of the A.S.M.E. Railroad Division, the executive committee of the Division appointed C. L. Combes, associate editor, *Railway Age* and *Railway Mechanical Engineer*, to the vacant position. The committee expressed its appreciation to Mr. Richardson for his work as secretary for the last fifteen years.



13,700 KW TURBOGENERATOR AT THE EAST WELLS STREET POWER PLANT, WISCONSIN ELECTRIC POWER COMPANY, MILWAUKEE

(During the A.S.M.E. Semi-Annual Meeting in Milwaukee, June 17–20, it is expected that this plant will be visited.)

Junior Group Activities

Philadelphia Juniors Brave St. Valentine's Day Blizzard

THE February meeting of the Philadelphia Junior Group fell on the night of the St. Valentine's Day blizzard. Braving the wind and snow, many of the members proved their hardiness by being on hand to hear a talk by Robert Oberholtzer, Junior A.S.M.E., and engineer, James Lees and Sons Co., on the subject of "Manufacture of Rugs and Carpets." Those who attended learned about the preparation of the wool and the details of construction of the three common types of rugs, the Axminster, the velvet, and the Wilton. The paper was followed by a motion picture of rug making, showing many views of the complicated weaving machinery.

On the Wednesday following the meeting, an inspection trip was made to the Freihoffer Baking Company plant. Here the Juniors had an opportunity to view the largest bakery under one roof in the United States. It was very interesting to see the diversified machinery together with the special equipment and controls.

S.R.O. Sign Put Out at Metro Junior Meeting

MORE than 100 Juniors crowded into room 1101 of the Engineering Societies Building on Feb. 13, filling up space which ordinarily accommodates 50. The subject of the Metropolitan Junior Group meeting was astronomy and featured papers on "Interesting and Significant Facts in Our Broader Universe," by Meyer Meadow, amateur astronomer, and "Casting the 200-Inch Mt. Palomar Telescope Mirror," by O. A. Gage, Corning Glass Works. Following the talks, a motion picture on the fabrication of the frame for the 200-inch mirror was shown.

At the March 5 meeting, the nomination of officers for the coming year took place and a talk and sound motion picture on commercial air transportation were presented. G. J. Wright, American Airlines, gave the talk and showed the film "Flagships of the Air." An interesting discussion on all phases of air transportation, and performance, construction, and maintenance of aircraft followed.

Bridgeport Junior Group Elects Viscusi Chairman

AT A meeting of the Bridgeport Junior Group in February, William E. Viscusi was elected chairman. He promises bigger and better programs during his term of office.

North Texas Juniors Arrange and Conduct Special Program

MEETING at the Dallas Museum of Fine Arts on Feb. 19, members of the North Texas Section saw the Juniors perform in a special program put on by them. Featured were a talk on "The Young Engineer in Industry," by Noble Sherwood; a paper describing "The Engineer on the Cooperative Plan," by Raymond Holland, student member A.S.M.E.; a report on "Unemployment Problems of Youth," by Leonard Cole; entertainment by Maurice Johnson, amateur magician; and, last but not least, substantial refreshments and sandwiches. Cigars, too. Credit for the excellent program is due to John K. Chattey and the rest of the Juniors in the Section.

With the Student Branches

A.S.M.E. Student Members Learn About Best Methods of Getting a Position

Branch Meetings Train June Graduates on Essentials of Application Letter, Personality, and Interview

MANY of the 117 Student Branches of the A.S.M.E. are holding special meetings during April and May for student members who are graduating in June in order to train them in the art of job getting. It doesn't matter whether a man has obtained a position already, this type of training is something that will be useful to him throughout his life. Opportunities for placement in the field of mechanical engineering are the best so far in many years. The positions are waiting for those who know the technique of unearthing them.

Newton D. Cook, manager of the San Francisco office of the Engineering Societies Employment Service, summarizes the methods in obtaining and keeping a good job in the following words: "Determine what you have to offer and what you want to do, find an employer for whom you want to work, get close enough to him by letter or in person to reach an agreement regarding his ideas and yours, and go to work to prove that you have what it takes." In other words, the school and the A.S.M.E. are willing to help a man all they can but, in the final analysis, it's up to the man to help himself.

Letter of Application

After a graduate has chosen the companies for which he would like to work, the number may be anywhere from ten to a hundred, he should get in contact with each one by letter. A suggested form for a letter of application, to be typewritten on good bond paper of $8\frac{1}{2} \times 11$ in. size, follows:

1234 South Street
Berkeley, Maine
May 1, 1940

Mr. John Smith, Chief Engineer
American Machinery Corp.
666 State Avenue
Middleton, Pa.

Dear Mr. Smith:

I am writing to you with respect to employment on the engineering staff of your company, on or after May 25 when I shall receive a B.S. degree in mechanical engineering. My major interest has been machine design and, in addition to required studies, I have had two elective courses on machine design and dynamics and a course in electrical engineering on rotating machinery. I am now preparing a bachelor's thesis on hydraulic drives for machine tools. It has been my desire to do work in machine design and, therefore, I am presenting for your consideration the following qualifications:

Personal Data:
Age—21
Height—5 ft, 11 in.
Weight—168 lb
American—born in Portland, Maine

Education:
Graduate, Main High School, Berkeley, Maine, 1936
Department of mechanical engineering, University of Berkeley, 1936 to date
My college studies also include courses in English, public speaking, commercial law, and economics

Activities:
Secretary, Student Branch, The American Society of Mechanical Engineers Tau Beta Pi, national senior scholastic honor society
Varsity track team, 1938 and 1939
Alpha Beta Gamma, social fraternity

Experience:
Drafting room, Ames Machine Co., Hoboken, N. J., summers of 1937 and 1938
Timekeeper, Maine R.R. shops, Portland, Maine, summer of 1939

References:
Mr. Charles Lock, chief engineer, Ames Machine Co.
Mr. Thomas Duffy, shop superintendent, Maine R.R.
Prof. James Jones, dept. of mechanical engineering, University of Berkeley

I shall be in Philadelphia during the week of May 12 at which time it will be possible for me to go to your office at your convenience for an interview.

Enclosure:
Photograph

Very truly yours,
(Signed) Richard Roe
Richard Roe

Personal Interview

The next step in the process of job getting is the personal interview. This may take place on the campus with the representative of one of the large corporations or with the recipient of the foregoing letter. George R. Beach, Jr., manager of the personnel department of du Pont, in a recent talk outlined the qualifications in which employers are interested. They are four in number, two of them are objective and are based on the student's college career. The first of these is academic standing because the success of the applicant in obtaining an education is indicated by his marks. The next qualification, extracurricular activity and participation. By this is meant campus activities and/or self-support, partial or whole. The other two qualifications are those of general appearance and of suitability for industrial employment. The former is important because sloppy appearance and eccentric dress only serve as barriers in obtaining cooperation from one's fellow workers. The latter qualification, which is not personality, is self-explanatory.

UNIVERSITY OF BRITISH COLUMBIA STUDENT BRANCH MEMBERS

Branch Meetings

Branch Library at British Columbia

A SPECIAL library for mechanical engineers has been established at the University of British Columbia by the A.S.M.E. STUDENT BRANCH. It consists of a room expressly built and equipped for this purpose and located in the mechanical building. The student members have cooperated to the fullest extent. Each member of the present graduating class has promised to donate a book upon graduation to the Branch Library. Among the officers of the Branch is the librarian who has complete charge of the room which is open only to A.S.M.E. student members.

ARIZONA BRANCH met on Feb. 8 and elected new officers for the coming term. They are

A. B. Pinkley, chairman; William Peters, vice-chairman; C. H. De Selm, secretary; and William Sargent, treasurer.

ARKANSAS BRANCH members went to Tulsa, Okla., on Feb. 28 to visit the Spartan Aircraft Corp., where they were taken through the factory and the adjoining flying school. At the meetings in February, papers were presented by B. Cumnock, Howard Jenkins, C. Morse, Pitts Jarvis, and T. A. Thompson.

Alabama Poly Prefers Name of Auburn

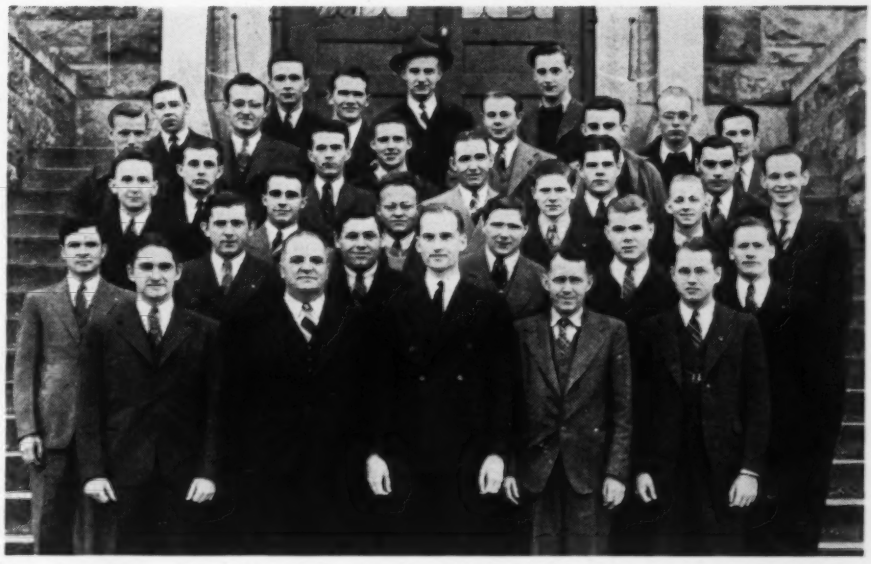
Just to be different, the secretary of the ALABAMA POLY BRANCH always refers to it as the AUBURN BRANCH. This "alias" has been used by almost every secretary since the establishment of the Branch in 1920. Anyhow, the AUBURN BRANCH had as speakers Dr. John Gallallee, University of Alabama, who spoke on "Design of Steam Plants," and R. A. Polglaze, secretary of the Birmingham Section, who invited the student members to the A.S.M.E. Student Meeting in Birmingham, Ala., April 1–2.

CALIFORNIA BRANCH had 80 student members at the annual banquet on Feb. 15. Jim Dinsmore led the singing, Bob Andresen acted as toastmaster, and Bob Komor invited everyone to take part in an inspection trip to an N.Y.K. ship on Feb. 21. Lloyd Taylor, executive secretary, Market Street Association of San Francisco, was the guest speaker. His subject was "Selling."

CALIFORNIA TECH BRANCH on Feb. 9 inspected the plants of the Southwest Welding and Machinery Co. in Alhambra, and of the Firestone Rubber Co. in South Gate.

Cincinnati Members Lose to Faculty

Following a meeting of the CINCINNATI BRANCH on Feb. 19, the student members engaged in a bowling match with the members of the engineering faculty. Much to the surprise of everyone, the "profs" won by two games out of three. Now the youngsters are demanding a return match.



STUDENT BRANCH MEMBERS AT UNIVERSITY OF KANSAS

COLORADO BRANCH members, not "having any business" for discussion at the Feb. 14 meeting, listened to a talk on sociology which was given by Dr. W. S. Bernard, assistant professor of sociology at the University.

COLORADO SCHOOL OF MINES BRANCH members listened to a very interesting report on Feb. 23. Prof. J. C. Read described with the aid of photographs the effect of turbulence of fluids in a glass pipe.

COOPER UNION BRANCH members on Feb. 16 saw how 10,000,000 bottles per eight-hour day are bottled at the Pepsi-Cola plant in Long Island City. During the weekly meetings in February, student papers were presented by William Lawrence and Robert Gordon.

COOPER UNION BRANCH (evening) at its meeting of Feb. 23 heard a talk given by Leo Strauss on "Automatic Feeders and Hoppers." Vice-chairman John J. Dishuck announced that the Branch had 125 members at the present date.

CORNELL BRANCH had 41 student members and 44 visitors present on Feb. 20 to see and hear a sound motion picture on "Heat and Its Control."

Detroit Has Music Meeting

As part of the talk of Rev. F. J. Quinn, S.J., who gave a paper at the Feb. 20 meeting on classical music, members of the DETROIT BRANCH heard recordings. Some of the music played included "The Blue Danube," "Now Is the Month of Maying," "The Mikado," and selections by Tchaikovsky, Verdi, Puccini, Victor Herbert, and Gilbert and Sullivan.

GEORGIA BRANCH reports the election of the following officers at the Feb. 13 meeting: R. M. Norman, chairman; G. B. Cauble, vice-chairman; and R. E. Mason, secretary.

JOHNS HOPKINS BRANCH on Feb. 21 had a lecture on "Air Conditioning," which was presented by E. Robert Kent, engineer, Air Conditioning, Inc.

IDAHO BRANCH met on Feb. 15 to accept from Daniel Beckm, regional manager, Chrysler Corp., a chassis of a 1939 Dodge. This very attractive cutaway model, finished in enamel and chromium, was hand built and represents a factory cost of more than $7000.

Illinois Host to Section

At the Feb. 16 meeting, ILLINOIS BRANCH acted as host to 95 student members of the Branch and to 25 members of the Central Illinois Section of the A.S.M.E. The guest speaker was Prof. H. F. Moore, who spoke on "What Fatigue of Metals Has Done to Design Problems."

2000 Student Members to Attend Ten Student Meetings

Society Officers and Staff Members Will Represent A.S.M.E.

MORE THAN 2000 student members of the A.S.M.E., out of a total membership of 6500, are expected to attend the ten Student Meetings of 1940 which start in Santa Clara, Calif., on March 29, and end with the last meeting in Worcester, Mass., on May 4. The list of Meetings and the dates were published on page 262 of the March, 1940, issue of MECHANICAL ENGINEERING.

In addition to the representatives of the Committee on Relations With Colleges listed in that table, the parent Society will be represented by Council members, C. E. Davies, secretary, and Ernest Hartford, assistant secretary.

The names of the officers and the meeting to be attended by each are as follows: Group I, Worcester, Mass., May 3–4, vice-president J. C. Hunsaker; Group II, Newark, N. J., Apr. 29–30, vice-president Francis Hodgkinson; Group III, College Park, Md., Apr. 25–26, past-president A. G. Christie; Group IV, Birmingham, Ala., Apr. 1–2, Council member J. W. Eshelman; Group V, Chicago, Ill., Apr. 15–16, Council member Guy T. Shoemaker; Group VI, Kansas City, Mo., Apr. 26–27, Council member Linn Helander; Group VII, Lubbock, Texas, Apr. 19–20, Council member W. R. Woolrich; Group VIII, Pullman, Wash., and Moscow, Idaho, Apr. 28–May 1, vice-president W. Lyle Dudley; Group IX, Salt Lake City, Utah, Apr. 19–20, Council member Frank H. Prouty; and Group X, Santa Clara, Calif., Mar. 29–30, president Warren H. McBryde.

At each of the ten Student Meetings, cash awards amounting to almost $100 and other valuable prizes will be distributed to those student members who present the best papers according to a board of judges. Last year, many of the winning contestants were offered positions by representatives of industries attending the various meetings. Then, each of the 2000 participants will be given souvenirs contributed by various companies throughout the United States.

VIRGINIA POLYTECHNIC BRANCH MEMBERS ON ALL-DAY INSPECTION TRIP, FEBRUARY 15

IOWA BRANCH held a special meeting on Feb. 14 at which Prof. Ralph Barnes explained the methods of obtaining a job upon graduation, including letter writing, technique of being interviewed, and selecting a job. Much was learned, especially by the seniors.

IOWA STATE BRANCH at its Feb. 22 meeting had 200 present to hear a talk on "Superfinish" given by John Petrie, Chrysler Corp. "Diesel engines" was the topic of the Feb. 28 meeting which featured a talk by A. Andrews, Nordberg Mfg. Co.

LOUISVILLE BRANCH members Altman and Strother were the student speakers at the Feb. 15 meeting.

MARQUETTE BRANCH in conjunction with the A.I.Ch.E. chapter visited the Wesley Steel Treating Co. plant on Feb. 13. After the tour, each member of the party was presented with a cigarette lighter and given sandwiches and beer.

Michigan Employment Clinic

MICHIGAN BRANCH sponsored an employment clinic for student members on Feb. 14 through a committee headed by Albert Furman. At the clinic, members of the faculty discussed the various types of mechanical-engineering positions, such as sales, research, design, and production. The actual technique of job getting was discussed, including letters of application, personal appearance, and interview. About 50 student members and 200 visitors were present at this very interesting session, reports Robert H. Jeffers, branch secretary.

MICHIGAN STATE BRANCH in cooperation with the other student engineering chapters on the campus sponsored the annual Engineers' Ball on Jan. 26. Decorations included a gigantic silver gear and pinion, 3000 blue and yellow balloons, a large yellow "E" made of balloons, and a suspension bridge for the band stand. Roger McIntyre, secretary of the Branch, rates it as the "super affair of the year."

MINNESOTA BRANCH had its winter bean feed on Mar. 8 in the Union. Beans, souvenirs, and entertainment provided the fun.

MISSOURI SCHOOL OF MINES BRANCH had a graduate as the speaker on Feb. 2. He was Ned Foster, class of '25, who is factory superintendent of the Curtiss-Wright Airplane Co. plant in St. Louis. On Feb. 21, the guest speaker was Maxwell C. Maxwell, who talked on materials handling.

NEVADA BRANCH did its part during Engineers' Day on March 9, by showing several mechanical exhibits.

Cartoons Aid N.Y.U. Members

Prof. Charles E. Gus, former honorary chairman of N.Y.U. BRANCH (mechanical, aeronautical, and evening), after five years of experimental research with visual aids to teaching, recently announced that he was ready to introduce into his regular courses in engineering mechanics "streamlined" methods of teaching complex problems. Among the innovations will be skeletonized models of complex machinery, progressive lantern slides, and animated cartoons depicting abstract engineering principles. He expects to produce one full-length film per semester.

NORTH DAKOTA BRANCH will celebrate the 60th Anniversary of the A.S.M.E. on April 6 with a party in the mechanical laboratory. Games, stunts, and dancing will be the features of the evening.

NORTH DAKOTA STATE BRANCH held a joint meeting with the A.S.C.E. chapter on Feb. 23. The showing of two films was followed by a talk on "Engineering Ethics," which was presented by Rev. Boyd, a Fargo minister, who used to be an engineer.

NORTHWESTERN UNIVERSITY reports that construction of its new $5,000,000 technology building is now starting. After the completion of the building, the Institute of Technology will offer courses on the cooperative plan under which students will alternate their classroom study with work in industry on a quarterly basis.

D. C. Jackson at Notre Dame

Col. Dugald C. Jackson, fellow A.S.M.E., was the guest speaker at the college of engineering of NOTRE DAME UNIVERSITY on Feb. 10. His address was on "The Part Played by Engineering and Architecture in the Development of Civilization," which was based on a series of articles he wrote for MECHANICAL ENGINEERING in 1938. At the Feb. 6 meeting of the NOTRE DAME BRANCH, K. L. Herrmann, consulting engineer, described and demonstrated his barrel-type internal-combustion engine.

OHIO STATE BRANCH members learned about the methods of getting a job from Professor Marquis at the Feb. 2 meeting.

PENNSYLVANIA BRANCH devoted its meeting of Jan. 24 to the subject of glass manufacture. J. Bygott, Pittsburgh Plate Glass Co., was the guest speaker.

PRATT BRANCH held meetings on two consecutive days. On Jan. 31, Alexis Dawydoff, glider expert, discussed gliding before 40 members. The following day, E. C. Paige, Ethyl Gasoline Corp., gave a talk and demonstration on leaded gasolines before 60 members.

F. L. Wilkinson at Purdue

Speaking on "Marine Engineering," Dean F. L. Wilkinson, Jr., member A.S.M.E., and head of the school of engineering at the UNIVERSITY OF LOUISVILLE, addressed the student members of PURDUE BRANCH on Feb. 21. There were 55 members and 10 visitors present.

R.P.I. BRANCH members met on Feb. 21 and learned how to prevent heat losses in the burning of coal through the use of pipe covering, soot blowers in boilers, and prevention of leaks. The medium of instruction was a motion picture, entitled "Coal Is King."

ROSE TECH BRANCH offered two talks by student members at the Feb. 19 meeting. Speakers were Arnold Jones and John Bartmess. Plans were discussed for celebrating the 60th Anniversary of the A.S.M.E.

Initiation at Stanford

All new student members of STANFORD BRANCH are formally initiated into the professional ranks of the A.S.M.E. at an annual banquet which, this year, was held on Feb. 28. With Chairman William A. Doble acting as master of ceremonies, the successful aspirants received their membership pins upon giving the correct answers to a series of quiz questions.

STEVENS BRANCH does its part in publicizing the meetings of the A.S.M.E. Metropolitan Section by having the school newspaper print the Section's program for the coming month. More than 300 students are enrolled in the Institute's graduate school. The most popular course is the new one on powder metallurgy as attested by an enrollment of 43.

SWARTHMORE BRANCH held its meeting of Feb. 11 at the home of Prof. Charles Thatcher. Charles Kane, Atlantic Refining Co., told the group of 20 how to sell themselves to employment managers.

130 Attend Texas Meeting

About 130 members and guests, including women, attended the Feb. 5 meeting of TEXAS BRANCH to listen to Maxwell C. Maxwell, who spoke on locks. Student papers at the Feb. 12 and 19 meetings were presented by Jack Bartels, Ray Woolrich, Jack Scanlan, John Medlin, and C. E. Smith.

TEXAS A.&M. BRANCH also had Mr. Maxwell as a guest speaker on Jan. 31. The turnout included more than 160 members and guests.

TORONTO BRANCH selected its entrant for the 1940 Student Meeting on Feb. 20. After papers were given by W. F. Woodley, J. C. Finlayson, F. F. Walsh, F. G. Murphy, and R. A. Greig, Mr. Murphy was selected as the winner by three graduate engineers.

VIRGINIA BRANCH members made a trip to Lynchburg, Va., on Feb. 13 in order to visit the plants of E. J. Lavine Co., Lynchburg Foundry Co., Mead Paper Corp., and Craddock-Terry Shoe Co.

V.P.I. BRANCH also had an all-day inspection trip which was made on Feb. 15 to Narrows and Glen Lynn, Va. Among the plants visited were those of the Celanese Co., Virginian Railroad Power Co., and the Appalachian Power Co.

Washington Has 200 at Meeting

The best meeting of the year for the WASHINGTON BRANCH was held on Jan. 25 according to the more than 200 members and guests who attended. "Die Casting the Modern Way" was the title of the motion picture shown through the courtesy of the Harvell Aircraft Co. At the Feb. 8 meeting, attended by 115, the showing of motion pictures on safety-glass manufacture was preceded by Edgil Robertson giving a short review of the contents of the February issue of MECHANICAL ENGINEERING.

Conference on Friction and Surface Finish at M.I.T.

A CONFERENCE on friction and surface finish will be held at Massachusetts Institute of Technology, June 5–7, 1940. The morning of each day will be devoted to the presentation of three technical papers, and the afternoon of each day to a discussion from the viewpoint of the machine-tool, automotive, aircraft, and oil industries. The nine papers to be presented include "Some General Aspects of Rubbing Surfaces," by A. F. Underwood, "Metallurgy of Surface Finish," by J. Wulff, "Preparation of Smooth Surfaces," by D. A. Wallace, "Surface Friction of Dry Metals," by H. Ernst, "Geometry and Quality of Metallic Surfaces," by S. Way, three papers on "Boundary Lubrication," by G. B. Karelitz and others, and "Wear," by H. W. Gillett. Further details are obtainable from Prof. J. C. Hunsaker, M.I.T., Cambridge, Mass.

Iowa Announces Summer Course in Motion and Time Study

THE University of Iowa is offering a special three-week course for people in industry interested in comprehensive training in motion and time study, waste elimination, cost reduction, and related subjects. To be held in Iowa City, Iowa, June 10–28, 1940, the course will be under the direction of Prof. Ralph M. Barnes, member A.S.M.E. Expenses for the three weeks include $60 for tuition, $15 for laboratory fee, and $15 to $24 for a room.

150,000 Books Available From Engineering Societies Library

Library Board Authorizes Loan of All Books to Members Under Liberal Rules

NO MORE will it be necessary for members of the A.S.M.E., regardless of residence, to forego the privilege of using the 150,000 books and bound periodicals contained in the Engineering Societies Library, New York, N. Y., because of inability to call in person. Since the policy of making loans to members from the duplicate collection of 10,000 volumes has proved so successful, the Library Board has now authorized the Director of the Library to lend practically any book from the complete collection under the following rules:

1 Volumes from the Library's general collection will be lent only to members in good standing of the A.S.M.E. and other Founder Societies, and to nonprivate and noncommercial libraries. Volumes from the duplicate collection will be lent to any person who establishes his responsible character to the satisfaction of the Director of the Library.

2 Volumes declared by the Director to be rare books or reference books will be lent only after approval by the Executive Committee of the Library Board.

3 Serial publications will be lent only after they have been bound.

4 A minimum charge of fifty cents per volume, which includes expense for insurance and postage to the borrower, will be made to all persons. (Borrower pays cost of return postage and insurance.)

5 For each volume retained by the borrower longer than one week, a rental of five cents per day will be charged. (There is no charge for the initial week except the cost of fifty cents.)

6 No volume from the Library's general collection will be lent for a period longer than ten days plus time for transit to and from borrower, except with the specific approval of the Executive Committee.

7 No individual may have more than three volumes on loan in his name at any one time, and no library may have more than five volumes in its name at any one time.

8 No loans will be made outside the continental United States and Canada.

Requests for loans should be addressed to the Engineering Societies Library, 29 West 39th Street, New York, N. Y. Members are asked to mention their A.S.M.E. affiliation when writing about loans, photostats, microfilms, and other services.

Photostats and Microfilms

Members of the A.S.M.E. may obtain photostats from the Library at a reduction of five cents from the regular price of thirty cents charged to nonmembers to cover the cost of processing and postage of each 11 × 14-in. white-on-black (negative) print on bromide paper. Black-on-white (positive) prints can also be supplied by copying a negative print at an additional cost of thirty cents less five cents discount for members. The prints contain one or two pages of the original volume, depending on its size. Reductions to approximately one half or enlargements to approximately twice the original size can be made, if desired, without extra cost. Unless enlargement or reduction is requested in the order, prints will be made the same size as the original.

Microfilm copies on 35-mm film can also be supplied by the Library at a cost of four cents per exposure (usually one page), with a minimum charge of $1.25 per volume or paper. For obvious reasons, copying in any form is con-

VIEW OF SIMONDS WINDOWLESS PLANT SHOWING END OF ONE OF THE EIGHT PRODUCTION LINES AND THE WALKWAY FOR VISITORS AT THE RIGHT

(Trip to this plant is planned during A.S.M.E. Spring Meeting at Worcester, Mass., May 1–3, see pages 338–339.)

WORCESTER, MASS., ART MUSEUM

(See pages 338–339 for details of A.S.M.E. Spring Meeting at Worcester, Mass.)

fined to Library property. However, an effort will be made to get for members from other libraries what is lacking in the Engineering Societies Library.

Photographic Stand for Members

For the benefit of A.S.M.E. members who wish to photograph any material in the Library, a photographic copying stand, complete with table and electric lights, is available without charge for use with the member's own camera.

A.I.E.E. Awards Lamme Medal to N. W. Storer

THE 1939 Lamme Medal of the American Institute of Electrical Engineers has been awarded to Norman W. Storer, retired consulting railway engineer, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa., "for pioneering development and application of equipment for electrical traction." The medal and certificate will be presented to him at the annual summer convention of the Institute, which is to be held in Swampscott, Mass., June 24–28, 1940.

Machine-Tool Electrification Forum, May 6–8

THE 1940 machine-tool electrification forum will be held at E. Pittsburgh, Pa., May 6–8, according to plans announced by the sponsors, Westinghouse Electric & Manufacturing Co. This annual meeting, started in 1936, makes possible round-table discussion of electrification problems and practices in machine-tool design.

Col. O. B. Zimmerman Awarded McCormick Medal

ANNOUNCEMENT has just been made by the American Society of Agricultural Engineers that the Cyrus Hall McCormick Gold Medal for 1940 has been awarded to Col. O. B. Zimmerman, member A.S.M.E., for his methods, his spirit of pioneering, and his tangible achievements in the field of agricultural engineering.

Swedish Engineers Award John Ericsson Medâl to Lindquist

AT a dinner meeting of the American Society of Swedish Engineers in New York, Feb. 10, the John Ericsson Medal of the Society was awarded to David L. Lindquist, member A.S.M.E., and chief engineer of the Otis Elevator Co., in recognition of his standing as a scientist, inventor, and engineer. Mr. Lindquist is a member of the A.S.M.E. Elevator Research Committee and of the Committee on Safety Code for Elevators.

U.E.T. Announces Death of Rector of Univ. of Louvain

ENGINEERS of the United States, who contributed funds after the World War of 1914–1918 for a clock and set of carillons for the University of Louvain in Belgium, will regret to hear the announcement made last month by United Engineering Trustees, Inc., of the death of Monsignor Paulin Ladeuze, rector of the University of Louvain, on Feb. 10.

International Conference on Flames and Furnaces

TO EXPLORE the precise characteristics of fire, an International Conference on Flames and Furnaces is scheduled to be held in September, 1940, at the Royal Institute in London, England. Scientific study of flame by methods of chemical kinetics and spectroscopy is opening new fields offering great engineering and industrial possibilities. One purpose of the conference will be to bring these developments to the notice of engineers and industrialists.

A Grand Vacation Trip!

IF YOU attend the 1940 A.S.M.E. Fall Meeting at Spokane (September 3–6, 1940), you can also enjoy an unusually attractive scenic trip, with visits to noteworthy technical developments like Grand Coulee Dam—an interesting and important technical program, and a host of good friends.

The following prices, of course, will be modified according to space desired and point of departure. Also, it has been suggested that tourist sleepers be provided instead of Pullmans which will mean a saving of about $40 on the prices stated.

Please use coupon on page 50 of the Advertising Section of this issue should you be interested in taking this trip. You will not be obligated by so doing, but will aid those making the arrangements.

Suggested Itinerary for A.S.M.E. Tour to Spokane Meeting

A three-week trip, Aug. 24–Sept. 14

(1) Visiting: Black Hills..... 2 days
Yellowstone Park..... 2½ days
Spokane Meeting..... 3 days
Sun Valley..... 1½ days
Rocky Mountain Park..... 3 days
New York to New York including all expenses (except meals at Spokane and local excursions or visits) lower berth, $375.

(2) *Alternative trip*, Aug. 27–Sept. 14, 3 weeks less 3 days
Visiting: Glacier Park..... 3 days
Spokane Meeting..... 3 days
Sun Valley..... 2 days
Rocky Mountain Park..... 3 days
New York to New York including all expenses (except meals at Spokane and local excursions or visits) lower berth, $325.

(3) *Alternative trip*, 2 weeks
Visiting: Yellowstone Park.... 2½ days
Spokane Meeting.....
(Including extra visits around Spokane, such as Coulee Dam, Coeur d'Alene mining district, etc.)..... 4 days
Glacier Park..... 3 days
New York to New York including all expenses (except meals at Spokane and local excursions or visits) lower berth $300 or less.

(4) *Alternative trip*, 18 days
Visiting: Yellowstone Park.... 2½ days
Spokane Meeting..... 4 days
Sun Valley..... 1½ days
Glacier Park..... 3 days
New York to New York including all expenses (except meals at Spokane and local excursions or visits) with lower berth about $325.

(5) *Alternative trip*, 3 weeks
Visiting: Glacier Park..... 3 days
Spokane Meeting..... 3 days
Sun Valley..... 1½ days
Yellowstone Park..... 2½ days
Black Hills..... 2 days
New York to New York including all expenses (except meals at Spokane and local excursions or visits) with lower berth about $375.

Local Sections

Coming Meetings

Anthracite-Lehigh Valley. April 12. Meeting to be held at Pottsville, Pa. Subject: "The Reduction of Noise," by Ernest J. Abbott, Physicists Research Co., Ann Arbor, Mich.

Baltimore. April 10. Engineers Club, 6 W. Fayette St., Baltimore, Md. Subject: "The Reduction of Noise," by E. J. Abbott, Physicists Research Co., Ann Arbor, Mich.

Boston. April 11. New Lecture Hall, Harvard University at 8:00 p.m. Subject: "An Alaskan Adventure," by Bradford Washburn, director, New England Museum of Natural History, Boston, Mass.

Central Illinois. April 9. Crève Coeur Room of the Pere Marquette Hotel, Peoria, Ill., at 7:45 p.m. Subject: "Loxology," by Maxwell C. Maxwell, assistant to president, Yale & Towne Manufacturing Co., New York City.

Central Pennsylvania. April 11. Meeting to be held at State College, Pa. Subject: "The Reduction of Noise," by E. J. Abbott, Physicists Research Co., Ann Arbor, Mich.

Florida. April 11. Hollywood Beach Hotel, Hollywood, Fla., at 9:00 a.m. Dean W. R. Woolrich, University of Texas, Austin, Texas, will address the A.S.M.E. Session. Program will be mailed to all Section members.

Los Angeles. April 4. Barker Brothers Building, 7th and Figueroa Sts., Los Angeles, Calif., at 6:30 p.m. Anniversary program commemorating the Sixtieth anniversary of the Society and the twenty-fifth birthday of the Los Angeles Section. This program will feature one of the Society's prominent members speaking on "The American Society of Mechanical Engineers" and will also have the past-chairman of the Section and as many of the Charter members of the Section present as possible.

New Orleans. April 8. This will be a General Section Meeting, A.S.M.E. Sixtieth Anniversary. Dean W. R. Woolrich, Dean of Engineering, University of Texas, Austin, Texas, will speak on the subject: "Quick Freezing and Its Applications in the South."

Norwich. April 12. New Engineering Building, University of Connecticut, Storrs, Conn. Subject: "Engineering Problems in Connection With Stratosphere Flight," by Charles H. Chatfield, director of research, United Aircraft Corporation, Hartford, Conn. Members of other Sections are cordially invited to attend.

Ontario. April 11. Hart House, Ontario, Canada. Subject: "Fuels and Oil-Burner Problems," by O. F. Campbell of the Sinclair Refining Co., Chicago, Ill.

Philadelphia. April 23. Engineers Club, 1317 Spruce St., Philadelphia, Pa. Subject: "Industrial Drying," by A. O. Hursthal, vice-president of the Proctor and Schwartz Company.

Pittsburgh. April 23. "Engineering Day." For detailed program see page 342 of this issue.

Providence. April 2. Providence Engineering Society Rooms at 8:00 p.m. Subject: "Marine Borers and Other Destructive Organisms in Rhode Island," by William F. Clapp, William F. Clapp Laboratories. The Sixtieth Anniversary Meeting will be combined with that of the Student Branch at Brown University. The subject will be "Robert Henry Thurston," by James P. Adams, vice-president of Brown University.

Rock River Valley. April 18. Rockford, Ill., at 7:00 p.m. Subject: "Some Aspects of Hydraulic Power Transmission," by Walter Ferris, vice-president and chief engineer, The Oil Gear Co., Milwaukee, Wis. The subject will be continued by R. M. Schaefer, manager, hydraulic department, Twin Disc Clutch Co., Racine, Wis.

San Francisco. April 28. Dinner at 6:00 p.m. Meeting at 7:30 p.m., Engineers Club, 206 Sansome St., San Francisco, Calif. Talk will be on "Glass." It is planned to arrange an inspection tour of the Owens-Illinois Pacific Glass Company.

Susquehanna. April 23. York, Pa. This will be a business meeting of the Section and election of officers will take place.

Tri-Cities. April 10. Dinner Meeting at the Blackhawk Hotel at 6:30 p.m. Subject: "Hundred Horsepower Hands," by Maxwell C. Maxwell, assistant to president, Yale & Towne Manufacturing Co., New York City.

American Engineering Council

Presents

The News From Washington and Elsewhere

Doctors Held Subject to Antitrust Laws

IN A decision of fundamental interest to all professional men the Court of Appeals of the District of Columbia recently ruled that the prohibitions against acts in restraint of trade in the Sherman Act are applicable to the medical profession and, by implication, to organized action by members of all other professions as well.

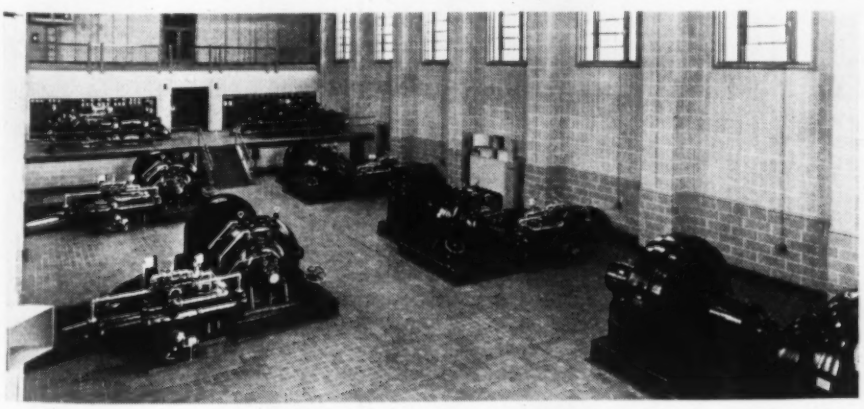
The case arose out of the opposition of the American Medical Association, the Medical Society of the District of Columbia, and certain other organizations and individuals to the Group Health Association, a cooperative association, the members of which paid regular dues into a fund used to defray their expenses for medical care and hospitalization. The medical societies, it is charged, conspired to prevent the successful operation of this plan by forbidding members to affiliate with this plan, upon penalty of expulsion, or to serve as consultants to doctors so affiliated. They are further alleged to have obstructed the admission of Group Health patients into local hospitals.

In December, 1938, a federal grand jury returned an indictment charging conspiracy in restraint of trade on the ground that these actions constituted a violation of the antitrust act. In July, 1939, the indictment was dismissed by the District Court on the ground that the practice is not a "trade" within the meaning of the act. It is this decision that has now been overruled in a unanimous opinion by a three-judge Court of Appeals. An appeal to the U. S. Supreme Court for a final determination of the issue is anticipated.

Certain significant quotations from the 16-page opinion are:

"The common law governing restraints of trade has not been confined, as defendants insist, to the field of commercial activity ordinarily defined as 'trade,' but embraces as well the field of the medical profession. . . . . We must hold that a restraint imposed upon the lawful practice of medicine . . . . and of a lawful organization for the financing of medical services to its members, is just as much in restraint of trade as if it were directed against any other occupation or employment or business . . . ."

"Defendants say that what they are charged with doing amounts to no more than the regulation of membership in the society and the



THE LOW-LIFT-PUMP ROOM OF THE WATER PURIFICATION PLANT OF THE MILWAUKEE WATER WORKS

(A trip is planned to this plant during A.S.M.E. Semi-Annual Meeting, Milwaukee, June 17–20.)

selection of the persons with whom they wish to associate; that under their rules disobedient members may lawfully be disciplined. . . . . We recognize that in personal conduct and in professional skill the rules and canons so established have aided in raising the standards of medical practice to the advantage of the whole country. . . . Notwithstanding these important considerations, it cannot be admitted that the medical profession may, through its great medical societies, either by rule or disciplinary proceedings legally effectuate restraints as far-reaching as those now charged. 'An act harmless when done by one may become a public wrong when done by many acting in concert.' . . ."

"Organizations and rules which have as their purpose the improvement of conditions in any particular trade or occupation, and the regulation of relations between traders, are.... beneficial rather than detrimental to the public interest. But when these same organizations go so far as to impose unreasonable restraints on the operating in their fields, they become subject to the prohibition of the Sherman Act. . ."

The Court's ruling constitutes a signal victory for Assistant Attorney General Thurman Arnold, who is currently carrying his drive against trade restrictions into fields hitherto regarded as exempt from prosecution. In the building-construction industry his campaign has already resulted in the return of 65 indictments naming 556 defendants, including 39 labor unions and 110 labor officials, as well as many contractors and their associates.

Engineering Projects Hit by Economy

CONTINUATION of the drive by Congress to reduce below budget recommendations appropriations for the fiscal year beginning July 1, 1940, has resulted in a number of cuts affecting engineering work of various kinds.

The War Department appropriation bill for nonmilitary activities was reported to the House of Representatives only after its Appropriations Committee had eliminated a $15,000,000 item to begin the construction of a third set of locks for the Panama Canal. In its plan the committee recommended $850,000 for the preparation of plans and specifications, stating that to begin construction at present would be "premature." This action was upheld by the House itself in passing the bill.

Also eliminated from the bill was $800,000 for dredging a channel at Wake Island in the Pacific Ocean. As passed by the House, the measure appropriated $70,000,000 for general flood control, or $63,000,000 less than the appropriation for the current year; $30,000,000 for flood control on the lower Mississippi River, a cut of $9,000,000 and $66,721,510 for river and harbor improvements, or nearly $30,000,000 below the current level. Also approved was $30,098,771 for work on the Panama Canal not connected with the new locks, but largely designed to strengthen its defenses.

Economy also trimmed the Interior Department appropriations, from which the Appropriations Committee cut almost $3,000,000, bringing the total down to about $119,000,000 as compared with $148,000,000 appropriated last year. Specific cuts included $1,247,000 from the U. S. Geological Survey, principally from a proposed fund for mapping strategic areas of military importance. This item represented an attempt to procure more funds for mapping, a proposal long favored by American Engineering Council. It was ruled out on the ground that an expenditure for military purposes should not include the Interior Department bill.

Supreme Court to Review Federal Rule Over Power

The much disputed question of how far up the tributaries of navigable streams the federal government can constitutionally extend its authority has at last reached the Supreme Court of the United States, which on March 4 agreed to review lower court decisions regarding the necessity for a Federal Power Commission license for the $11,000,000 hydroelectric development of the Appalachian Power Company on the New River at Radford, Va.

This case has had a tangled legal history extending over the last fifteen years, during which the plant has been built and placed in operation. The power company has consistently refused to apply for a federal license on the ground that the New River is not navigable and federal jurisdiction does not apply. The government contends that the New River is legally a navigable stream and that, furthermore, the project will affect navigation on the Kanawha River, into which it flows, and the Ohio River further down. It asks an injunction prohibiting operation of the plant until a license is applied for and granted.

A ruling that the plant requires a license will subject the power company to certain requirements regarding operation of the plant, and will also mean that it can be recaptured by the government at the end of 50 years.

Meanwhile Governor Leon C. Phillips of Oklahoma, who recently was refused permission by the Supreme Court to bring a suit to enjoin the construction by the federal government of Denison Dam on the Red River between Oklahoma and Texas, opened up a new battle by declaring that he would use troops, if necessary, to prevent the flooding of state roads and bridges due to the imminent completion of the Grand River Dam, a PWA financed project being built by a state-created authority.

War Affects United States

Several repercussions of the European War upon the economy of the United States have been noted during the last month. Figures compiled by the Maritime Commission indicate that since September 15, 1939, 106 vessels have been transferred from American registry as the result of sales to citizens of other countries, as compared with only 54 during the entire year preceding the outbreak of the war. The vessels include all types of ships from small motorboats, tugs, and barges, up to large freighters and tankers. In age, they range from 20 to 50 years.

News-association reports indicate that plans of Great Britain and France to spend an estimated $1,000,000,000 in this country for the purchase of airplanes are temporarily in suspense pending approval by the Allied Supreme War Council and the working out of a priority plan with the American Army and Navy.

Great Britain's action in forbidding vessels to carry coal from Germany to Italy may result in the purchase of considerable amounts of fuel in this country. Unofficial reports from Rome indicate that the Italians are quietly negotiating for the purchase of some 3,000,000 tons of bituminous coal in the United States, provided suitable credit arrangements can be made.

Men and Positions Available

Send inquiries directly to
Engineering Societies Employment Service
29 West 39th St. New York, N. Y.

MEN AVAILABLE[1]

TECHNICAL GRADUATE, 42. Eighteen years' varied experience in railway and railway supply. Familiar design, construction, operation, maintenance of steam and electric locomotives. Desires responsible position railway engineering, maintenance, or sales. Me-441.

MECHANICAL ENGINEER, 33, married; University of Cincinnati graduate. Three years research with Westinghouse; 6 years design on heavy mechanical equipment. Desires permanent connection as designer or plant engineer. Me-442.

MECHANICAL ENGINEER, graduate M.I.T.; long and varied experience in industrial-plant engineering; power, process, and maintenance; licensed operating and professional engineer. Desires connection in executive charge of engineering work. Me-443.

ENGINEER, 30, married, M.E. and M.B.A., employed. Has worked through shop, foundry, and office from hand trucker to plant engineer. Also selling. Interested in sales engineering or assistant executive of operations. Me-444.

MECHANICAL ENGINEER, Cornell 1923. Experienced in development work on machinery and tools, shop processes, automotive parts, street-railway equipment. Also experienced in wage incentives, manufacturing specifications, cost analysis, and reduction. Me-445.

[1] All men listed hold some form of A.S.M.E. membership.

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Peace and security, too, can come out of a slide rule

WE'RE not unlike you engineers in being both the masters and the slaves of mathematics. Yet the mathematics of the engineer and the actuary, often as like as peas in a pod, lead to widely different ends. Your calculations find ultimate expression in a new machine or a manufacturing technique, ours come to light in the peaceful security of a widow, the pleasant old age of a man who has done his job well.

Perhaps it is this mutual dependence upon the accuracy of figures that has led so many engineers to look upon life insurance as the safest, surest way of providing for their own and their families' future economic security.

It is this same regard for the incontestability of figures which has, perhaps, accounted for the extent to which engineers prefer the Northwestern Mutual. For the engineer can see, in independently published reports, specific dollars-and-cents evidence that Northwestern Mutual insurance costs are exceptionally low. And the more carefully he analyzes this company, the more evident it becomes that this low insurance cost is attributable to qualities and practices which are demonstrably sound.

But in other regards, the engineer finds in The Northwestern Mutual an institution designed specifically to serve him. It is truly a "policyholders' company." Its owners are its policyholders. Its trustees, its officers, its agents have—as policyholders—a unity of interest with the entire group of 700,000 men and women who hold more than a million Northwestern Mutual policies.

The equality of selection in this group, the persistency with which they hold their policies, contribute both to the thoroughgoing mutuality of this company as well as to its enviable record for its low cost.

Talk to a Northwestern Mutual agent. Ask him for factual proof of how this company ranks from the standpoint of cost. Here is something you can "sink your slide rule into" to see just how you, too, can have peace of mind and security for your own and your family's future.

The Northwestern Mutual
LIFE INSURANCE COMPANY
OVER 700,000 MEMBERS
MILWAUKEE, WIS.

THE NORTHWESTERN MUTUAL

Life Insurance Company, Milwaukee, Wisconsin

ASSISTANT TO TECHNICAL EXECUTIVE, graduate mechanical engineer. Experience as first-class machinist and draftsman, now employed as design and development engineer on deep- and shallow-well pumps. Married. Location, secondary. Me-446-207-Chicago.

MANUFACTURING EXECUTIVE, 48, married. Design and production gasoline, Diesel, and aircraft engines; autos, airplanes, special machinery. Installation and operation machine shops, foundries, forge, and stamping plants; cost and accounting methods. Me-447.

Coming Civil Service Tests

U. S. CIVIL SERVICE COMMISSION:

Senior inspector, engineering materials, $2600 a year; and inspector, engineering materials, $2000 a year (mechanical and hulls options). Applications to take part in the open competitive examinations must be on file in the Commission's office in Washington, D. C., not later than April 8 if received from states east of Colorado, and not later than April 11 if received from Colorado and states westward. The place of employment for these positions is the Navy Department for duty in the field wherever assigned.

Senior inspector, ordnance material, $2600 a year; inspector, ordnance material, $2300 a year; associate inspector, ordnance material, $2000 a year; assistant inspector, ordnance material, $1800 a year; junior inspector, ordnance material, $1620 a year. Applications will be considered and rated approximately as received until May 22, 1940, unless an eligible register sufficient to meet the needs of the Ordnance Department, U. S. Army, is obtained sooner, in which event due notice will be given.

Further information and application forms may be obtained from the U. S. Civil Service Commission, Washington, D. C., or from one of its local offices in first-class post offices.

Fellowships

BATTELLE MEMORIAL INSTITUTE:

Research-associate appointments are to be made for one year, including vacation, and may be extended for a second year. The salary is $1800. Those appointed will work full time on approved research projects under the supervision of the Battelle technical staff. The projects assigned are fundamental or general ones, leading to the publication of information that will be useful to science and industry.

Young men who are university or college graduates and who have shown exceptional aptitude for research, either in graduate or in a brief industrial experience, are eligible. Preference will be given to those who have majored in physics, physical chemistry, organic chemistry, chemical engineering, metallurgy, fuels, or ceramics, and especially those who have completed their Ph.D. training.

Applications, which must be submitted not later than May 1, 1940, and further information may be secured by writing to Clyde E. Williams, director, Battelle Memorial Institute, Columbus, Ohio.

MECHANICAL ENGINEER, 21, B.S., 1938, single, 1½ years with gas-utility company. Desires opportunity for experience leading to permanent engineering position. Now employed. Available on two weeks' notice. Me-448.

RECENT GRADUATE ELECTRICAL AND MECHANICAL ENGINEER, 28, single, ambitious. Desires opportunity for experience leading to responsible engineering position. Interested in sales and production. Me-449.

MECHANICAL ENGINEER, 12 years' experience designing, estimating, drafting of ventilating and air conditioning systems, design and installation of dust-collecting systems. Thorough knowledge of duct design and construction, piping layout. Me-450.

MECHANICAL-CIVIL ENGINEER, DESIGNER, 30, registered professional engineer; European and American education; 12 years' practical experience, hydraulics, light and heavy machinery; 4 years responsible charge; 2 years consulting. Five languages. Me-451.

MECHANICAL ENGINEER, 34. Five years' experience executive engineer conducting surveys and preparing reports. Well-acquainted with machinery industries. Good background industrial economics and statistics. Author reports and papers. Wishes position assistant to executive or consulting firm engaged in engineering and surveys. Me-452.

INDUSTRIAL ENGINEER, available chief industrial engineer, director of training, works manager, or assistant. Eighteen years' experience supervision, foreman training, factory layout, labor utilization, time and motion study, standards, budgets, cost reduction, inventory production control, industrial relations. Me-453.

MECHANICAL ENGINEER, 42, professional license, capable of making efficiency and heat-balance computations, power-plant surveys, and cost analysis. Desires connection in power field. Me-454.

INDUSTRIAL ENGINEER, B.S.E.E., Tau Beta Pi. Graduate study in acoustics. Two years industrial engineering, time-study experience in Bedaux, and piecework systems in manufacturing. One year's experience oil fields; six months geophysical office. Me-455-365-C-5-San Francisco.

Demand for Mechanical Engineers Continues

ACCORDING to a study made of the type of positions received from employers by the New York office of the Engineering Societies Employment Service within the last few weeks, it is observed that 62 per cent call for mechanical engineers, 14 per cent for civil engineers, 10 per cent for chemical engineers, nine per cent for electrical engineers, and five per cent for mining or metallurgical engineers.

Complete figures for January, 1940, of all placements made by the three offices, which are located in New York, Chicago, and San Francisco, indicates an increase of 13.2 per cent over the same month in 1939. The placements in the different fields of engineering during the two months were as follows:

	Jan., 1939 Per cent	Jan., 1940 Per cent
Civil	41	10
Mining	15	21
Mechanical	34	42
Electrical	5	25
Chemical	5	2
Total	100	100

POSITIONS AVAILABLE

INSTALLATION ENGINEER, 30–40, graduate mechanical engineer with at least 5 years' experience in installation of intricate industrial machinery. Must be good organizer and know how to handle men. Considerable traveling. Salary, $4000–$5000 a year. Location, New York State. Y-5373.

MECHANICAL ENGINEER with general knowledge of machine tools and other metal-working machines such as used in railroad shops, shipyards, aviation plants, and shell factories. Must be qualified to assist on technical matters, to prepare quotations, etc. Knowledge of foreign languages not essential but helpful. Man of English or Scandinavian origin preferred. Headquarters, New York, N. Y. Y-5378.

MECHANICAL ENGINEER to act as superintendent of machine shop employing 18 machinists; must take complete charge of work and act as plant-maintenance engineer of entire plant, including powerhouse. Applicant should have knowledge of textile printing and be able to lay out and design special equipment. Location, New England. Y-5383.

TREASURER AND COMPTROLLER with at least 5 years' experience with manufacturing company. Experience with die-casting, spinning, and stamping concern beneficial. Location, East. Y-5384.

ASSISTANT FACTORY MANAGER, 37–45, for company manufacturing instruments and small parts. Must have experience with similar organization. Location, New Jersey. Y-5386.

SUPERINTENDENT for steel foundry, 30–45. Must be capable of handling men and have experience and ability in manufacture of both large and small intricate steel castings, subjected to high pressure in service. Location, Pennsylvania. Y-5392.

DEVELOPMENT AND RESEARCH ENGINEER, 30–45, for company manufacturing automatic temperature-control equipment (pneumatic type). Experience on pneumatic instruments and pneumatic valves preferred. Location, Middle West. Y-5399-C.

TOOL DESIGNERS AND TOOL TROUBLE MEN. Designers with at least 5 years' experience in tool design. Trouble men to iron out shop difficulties in new tool designs; must be able to use machine tools. Location, New Jersey. Y-5405.

OPERATION SHEET WRITERS AND SKETCHERS. Knowledge of machine-shop operations necessary for writers, while young men with general machine-shop experience acceptable for sketchers. Salary, $125–$175 a month. Location, New Jersey. Y-5406.

MECHANICAL ENGINEER, 35–45, with textile experience, to head research and development

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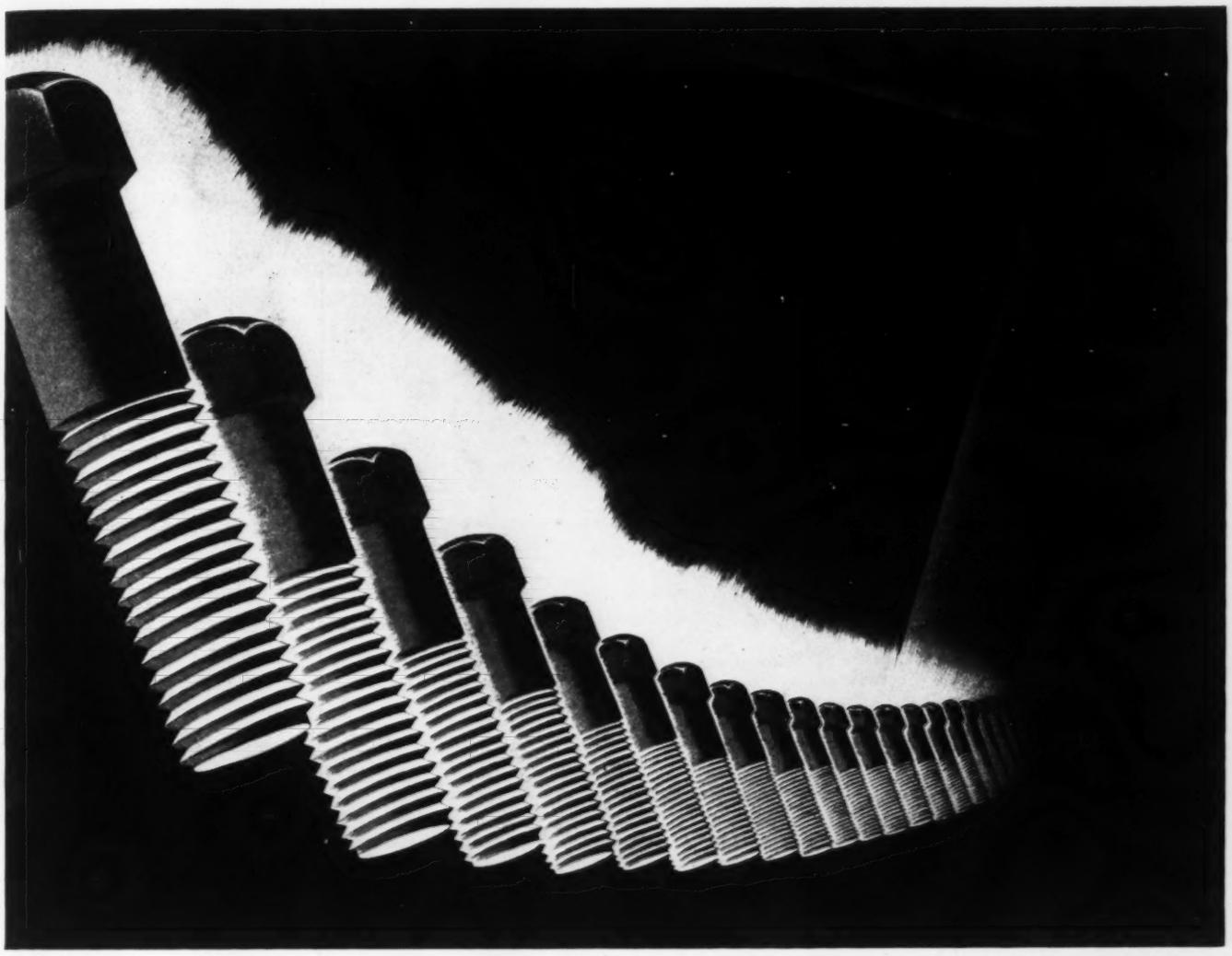

QUALITY UP—COSTS DOWN

When a change in material specifications reduces fabrication costs, and at the same time turns out a better product, there's something for everybody to cheer about.

Molybdenum steels are doing just that in many instances. Many manufacturers, for example, standardize on Chrome-Moly (SAE 4140) for bolts. Easier machining brings economies in tool expense and machining time—not much per bolt but a big saving in the aggregate. And the better physical properties of the steel bring better service performance in the product.

There may be places in your own specifications where the use of Molybdenum steel will simplify production, improve the product or both. Our book "Molybdenum in Steel", is filled with practical data which will help you recheck your specifications. It is sent free on request to interested production engineers and executives.

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